U.S. WAR DEPT.

Technical manual

Wire telegraphy

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WAR DEPARTMENT

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WIRE TELEGRAPHY

July, 15, 1942

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TECHNICAL MANUAL
No. 11-456

WAR DEPARTMENT,
WASHINGTON, July 15, 1942

WIRE TELEGRAPHY

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SECTION I

SINGLE-LINE TELEGRAPHY

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1. General.—*a. Importance.*—The importance of telegraphy to military communication can hardly be over-estimated. It is more rapid, reliable, and exact than any other method of electrical transmission of messages. The telegraph operator can work over a poor line at speeds which the radio operator cannot maintain. There is usually no delay for encoding and decoding of messages sent by telegraph. When static makes radio transmission difficult or impossible, the telegraph is unaffected. A few pounds of equipment will put a telegraph channel into operation over wires that must be laid to provide telephone communication. These advantages are often overlooked by the communication officer.

b. Scope.—This text proposes to give only a very elementary explanation of the telegraph apparatus and methods which are of interest to communication officers. Single-line telegraphy, which will be discussed in succeeding paragraphs, has a wide military application and is also the basis on which other systems are developed. It be may defined as telegraphy in which operation in both directions may be effected but not at the same time.

2. Sounder.—The sounder is the instrument from which the signal is read, and is illustrated in figure 1. As can be seen from the figure, it consists of an electromagnet of two coils and an armature which is held away from the coils by the spring pushing against the

sounding bar to which the armature is attached. When a current flows through the coils of the electromagnet, the armature is attracted and moved downward; a set screw in the right hand end of the sounding bar strikes the frame beneath it, giving a click. The armature remains down until the coils are no longer energized, then the spring forces the pivoted sounding bar up. The latter strikes the upper set screw, giving another click. Due to the construction of the apparatus the two clicks are dissimilar in sound; the interval between them determines by its length whether the character is a dot or a dash. For satisfactory operation, the sounder should be adjusted so that, when the armature is in the operated position, it is as close as practicable to the pole pieces without actually touching them. This clearance can be set by

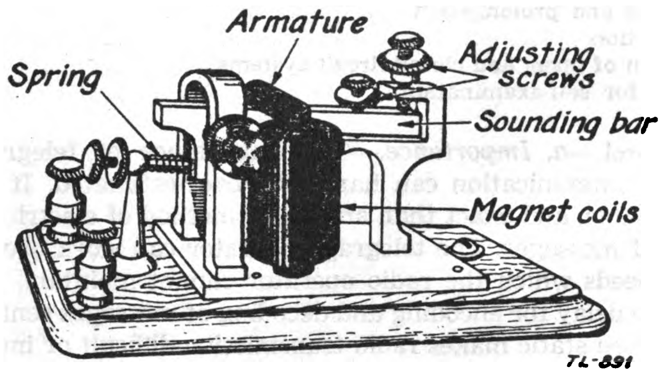

FIGURE 1.—Telegraph sounder.

means of the adjusting screw on the sounding bar, using a sheet of writing paper as a thickness gage. The travel of the sounder bar is usually set at about $\frac{1}{16}$ of an inch. This setting is made by means of the adjusting screw on the sounder frame, after the proper armature clearance has been set. The tension of the sounder spring is adjusted so that the sounder operates satisfactorily and produces the type of sound desired by the operator. After the sounder is properly adjusted, all lock nuts must be securely tightened, or the sounder will vibrate out of adjustment in a few minutes of use.

3. Circuits.—*a. Closed-circuit system.*—It is obvious that if a sounder were placed in a circuit such as shown in figure 2, an operator could send a message by operating the key and thus actuating the sounder.

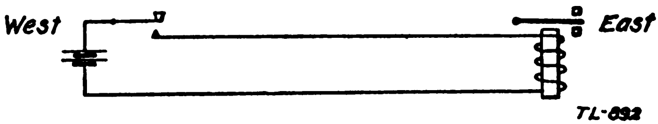

FIGURE 2.—One-way closed-circuit telegraph system.

It can also be seen that with this circuit there is only one-way transmission, that is, East cannot send any message to West. To get two-way transmission, a key and a sounder are used at each end, as in figure 3.

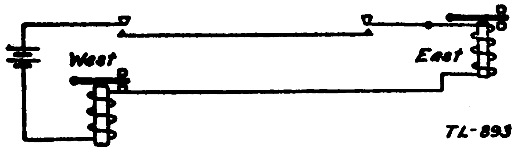

FIGURE 3.—Two-way closed-circuit telegraph system.

In figure 3, it is apparent that, since the circuit is broken in two places, one operator must hold his key closed while the other sends. To overcome this difficulty a short-circuiting switch is placed at each key, by means of which the operator closes the line when he is not sending. (See fig. 4.)

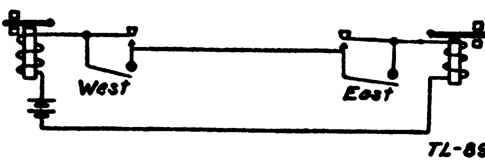

FIGURE 4.—Two-way closed-circuit system with short-circuiting switch.

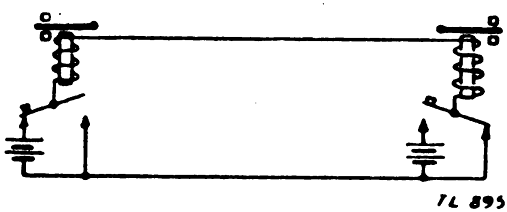

FIGURE 5.—Open-circuit telegraph system.

When neither operator is sending, the circuit is closed and current is flowing. This system is called the closed-circuit system and is the one in common commercial use in the United States. Another system, in general use elsewhere, is the open-circuit system, which is illustrated in figure 5.

b. Open-circuit system.—The differences between the two systems should be noted. The closed-circuit system requires the use of a key with only a single contact; The open-circuit system key has a front and a back contact, the key being held closed on the

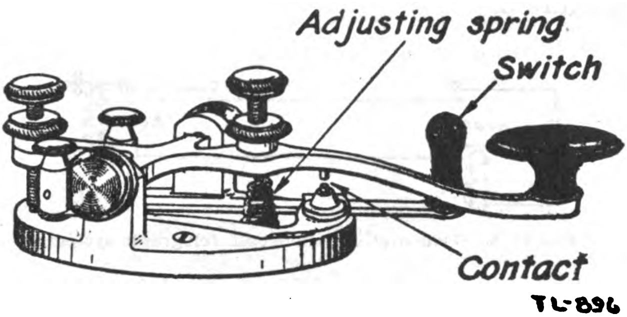

FIGURE 6a.—Closed-circuit telegraph key.

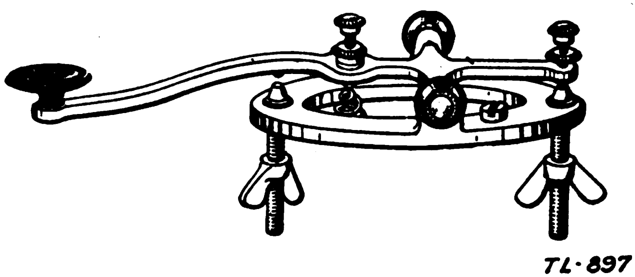

FIGURE 6b.—Open-circuit telegraph key.

back contact by a spring when the operator is not sending. The closed-circuit system uses only one battery; the open-circuit system must have at each station enough battery to operate the entire circuit. In the closed-circuit system, current flows in the line at all times except while spacing between the dots and dashes and between characters. In the open-circuit system, current flows only while dots and dashes are being made. These are the principal differences; the advantages and disadvantages of each will be

discussed later. In figures 6a and 6b are shown the closed- and open-circuit types of key.

c. Ground-return circuit.—Return to a consideration of the closed-circuit system and consider the modification which must be made in the circuit of figure 4 in order to make it more efficient and economical. First of all, wire may be saved by using a ground return, that is, by making the earth serve as one conductor of the circuit. The ground-return circuit will also reduce maintenance and will have a lower resistance than will a complete metallic circuit, if low resistance grounds are obtained. This is of importance because it means that a smaller voltage will be required to produce the minimum current necessary to operate the system. The ground-return has certain inherent disadvantages, the chief of which are:

(1) Contrary to the assumption often made, the earth is not everywhere at the same potential; there are actually considerable differences of potential between different points on the earth's surface. Such a difference of potential may oppose the battery which is driving current through a circuit, and thus require the use of additional battery to neutralize its effect.

(2) Induction from neighboring power circuits is greater for a ground-return circuit than for a metallic-return circuit, since on a properly transposed metallic circuit the same voltage is induced in each of the two conductors.

(3) The ground-return circuit is more susceptible to earth-current disturbances accompanying the Aurora Borealis than is the all-metallic circuit.

(4) In Army field telegraph systems, the ground-return circuit is more susceptible to interception by the enemy.

(5) The use of the ground-return requires that a ground be made at each terminal station. This must be a good ground; that is, one of low resistance. Methods of obtaining grounds are discussed in section III.

In general, it may be said that the advantages of the ground-return circuit outweigh its disadvantages for army use.

d. Relays.—(1) The next modification to be made in the circuit under development is made by the characteristics of the sounder. To make readable signals, the sounder must give sharp distinct clicks. Therefore the magnetic field of the coils must be strong. This strong field might be developed in either of two ways; by means of a large current flowing through a few turns or a small

current flowing through many turns. The latter method is the one chosen, since it is less wasteful of energy. The sounder operates most satisfactorily when the current through its coils is always the same. But the current in a telegraph line may vary widely due to various conditions, chief of which is weather.

(2) Operation is improved by removing the sounder from the circuit and by putting in its place an electromagnetic device called a relay. The relay has an armature which is held away from the coils by a spring; current in its coils pulls up the armature. The sounder is connected in series with a battery, the relay armature and a contact which the relay armature strikes when pulled up. Current in the coils of the relay pulls up the relay armature, and the relay armature, striking its front contact, closes the sounder circuit. Closing the sounder circuit energizes the sounder coils and pulls down the sounding bar. When the main line circuit is broken, the relay armature falls back under the action of its spring and opens the sounder circuit; the sounding bar is then pulled up by the spring of the sounder.

(3) The modified circuit is shown in figure 7. The circuit consisting of the battery, sounder, relay armature and the armature contact is called the local circuit; the circuit containing the relay, key, battery, line, and ground is called the main line. The relay is pictured in figure 8. The relay has the advantage that is requires

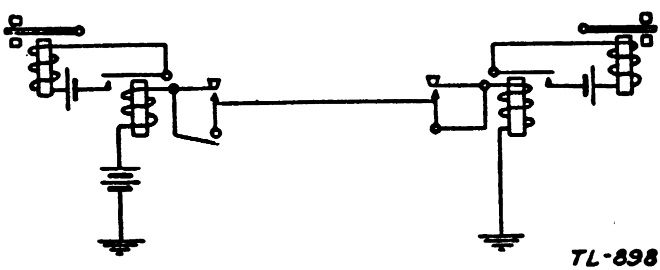

FIGURE 7.—Closed-circuit system with relays.

only a small current to operate it. The relay does not have to make any click; it has only to close the local circuit. It is immaterial whether or not the relay strikes its contact with definite force; so long as it strikes the contact at all, the local circuit will be closed, and the sounder gives the same click regardless of line conditions. Several adjustments are provided on this type of relay. First, the armature stop should be adjusted so that when the armature rests against the stop, the armature will be perpendicular to the in-

strument base. The armature contact should then be adjusted to reduce the armature travel to the minimum necessary to interrupt

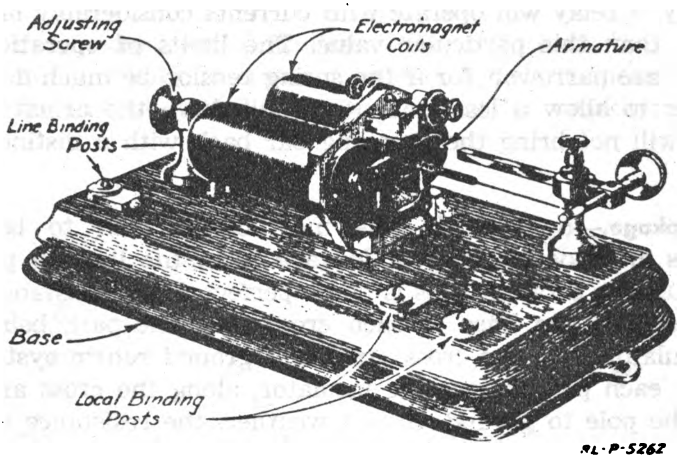

FIGURE 8.—Telegraph relay.

the line current. This motion will normally be of the order of 1/32 inch or less. The armature spring should then be adjusted, with the relay in position in which it is to operate, to exert just sufficient tension to retain the armature against the armature stop when no current is flowing. Further adjustment of this spring is seldom required. Under no circumstances is it ever necessary to exert great tension with this spring. These preliminary adjustments having been made, the relay is ready to be connected into a circuit. The operation of the relay in the circuit is adjusted by means of a large adjusting screw on the ends of the coils opposite the armature. Operating this screw changes the position of the coils mechanically with respect to the armature and provides sufficient flexibility for practically all purposes.

(4) The following information regarding relays and sounders should be noted.

Instrument	Resistance	Normal Operating Current
Main-line relay	75 ohms	80 milliamperes
Main-line relay	150 ohms	40 milliamperes
Main-line relay	250 ohms	25 milliamperes
Local sounder	4 ohms	250 milliamperes
Local sounder	20 ohms	175 milliamperes
Main-line sounder	150 ohms	40 milliamperes

Of these the 150-ohm relay and the 20-ohm sounder are the most commonly used. The normal operating current is the one sought. Actually, a relay will operate with currents considerably larger or smaller than this particular value. The limits of operation of a sounder are narrower, for if the spring tension be much decreased in order to allow a less current to pull down the armature, the spring will not bring the sounding bar back with a distinct click.

4. Leakage.—*a. General.*—The modification next to be made requires an understanding of leakage from the line. In practice, the insulation between lines is never perfect. High resistance paths exist between the lines at each cross arm, the path being over the insulators and the cross arm. In a ground return system, the path at each pole is over the insulator, along the cross arm, and down the pole to ground. In wet weather, the resistance of these paths is greatly lessened and may be only a small fraction of its dry weather value. All of these paths are in parallel, and their joint resistance is the resistance of one divided by the number of paths. Fortunately we need not consider the effect of each of these paths in turn because it may be proved mathematically that a line having uniform leakage may be replaced by a line having a concentrated leakage resistance at the middle, and that the currents at the two ends of this line will be the same as for the line which was replaced. The leakage of a telegraph line is not uniform, since it occurs only at poles, but it is nearly enough so to permit the use of this treatment with a high degree of accuracy.

b. Example.—Such a line is shown in figure 9, and the currents under different conditions may be computed as follows:

(1) *West sending.*—When West's key is open, no current flows through either relay. When West closes his key, the current through West's relay is 50 milliamperes and the current through East's relay is 40 milliamperes.

(2) *East sending.*—When East's key is open and West's switch is closed, no current flows through East's relay but there is a path through West's relay out over the line to the leakage resistance, down through the leakage resistance to ground and back to battery. Eighteen milliamperes flow through this path when East's key is open. When East closes his key, the currents are as in the

preceding paragraph, 40 milliamperes through East's relay and 50 milliamperes through West's relay.

5. Working margin.—*a. Definition.*—The difference between the current in a receiving instrument, when the distant operator's key is marking and when it is spacing, is called the working margin.

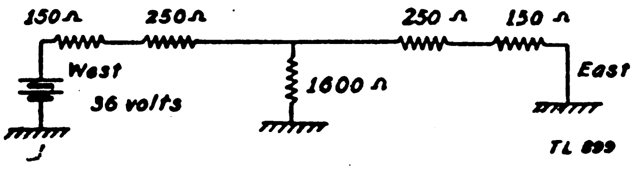

FIGURE 9.—Closed-circuit system with single battery, showing leakage.

In the closed-circuit system, a key is spacing when it is open and marking when it is closed. In the open-circuit system, the back contact of the key is made for spacing and the front for marking.

b. Examples.—(1) *Single battery.*—With the circuit of figure 9, East has a working margin of 40 milliamperes but West has one of only 32 milliamperes. The circuit is meant to work both ways and obviously it is not working equally well both ways. Had it been wet weather and the leakage resistance cut down to, say 400 ohms, East's working margin would have been 30 milliamperes (30−0=30) but West's would have been 15 milliamperes (60−45=15). Under such conditions, East could receive very satisfactorily but West might have difficulty in adjusting his relay to pull up on 60 milliamperes and release on 45 milliamperes. Seventeen milliamperes is considered by many as the lowest satisfactory working margin for the type relay which has been discussed.

(2) *Divided battery.*—The following happens when the battery is divided as in figure 10. (The leakage resistance of 400 ohms has been assumed since it was the critical value in the case discussed above.) When either key is closed with the key at the opposite end open, current flows through the relay at the closed key end. In figure 10, this current will be 22.5 milliamperes. When both keys are closed the current will be the same through each relay, 45

milliamperes. (This result may be arrived at either by the use of Kirchoff's laws or by noting that the midpoint of the line is at ground potential since half of the battery is at either end.) With the circuit shown in figure 10, both operators have the same working margin and this working margin is 50 percent greater for West

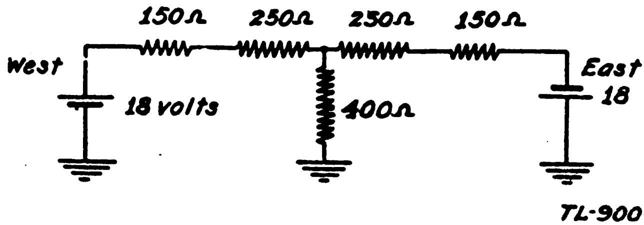

FIGURE 10.—Closed-circuit system with divided battery, showing leakage.

than it was with the hookup of figure 9. Reception is still good for East and it has been greatly improved for West.

6. Complete circuit.—The preceding example makes clear the modification necessary in the circuit of figure 7; the modified circuit appears in figure 11. In the latter figure, a milliammeter has been added at each end to enable the operator to read the current which flows through his relay when the distant key is opened and closed, thus learning his working margin.

7. Power source.—*a. Means.*—In all of the preceding diagrams, battery has been shown as the source of power; a direct-current generator or suitable rectifier operating on commercial alternating current, and producing suitable values of direct current, would have served equally well. These latter are used where sufficient power is needed to justify its installation, otherwise battery is more suitable.

b. Voltage.—The resistance of lines will obviously vary with their length, and a specific voltage is necessary for each to give the proper operating current. It would require a separate battery for each line if the voltage were fitted to the line; it is more economical to have one or more power supplies and to cut the voltage furnished by them down to the requirements of an individual line by inserting resistance between the power supply and the line. Thus one power supply may be used to serve several lines, each requiring a different voltage.

c. Protective resistors.—Aside from the resistances used as just explained, a resistance is connected in series with each power supply to prevent damage to it in case of short circuit within the office itself or at the switchboard. The resistance so used is 2 or 3 ohms per volt of output.

d. Protection from extraneous voltages.—The office equipment must be protected as well as the power supply generator; this protection must be against high voltages which tend to break down insulation and against high currents which tend to burn out the wiring. Lightning arresters are installed to ground the high voltages induced by lightning discharges and fuses are used to protect against short circuits or crosses with power wires. Heat coils are also employed. These devices are the same as, or similar to, those used in telephony and will not be described. Protective devices are installed wherever open lines join aerial, underground, or submarine cable and at all points where wires enter buildings.

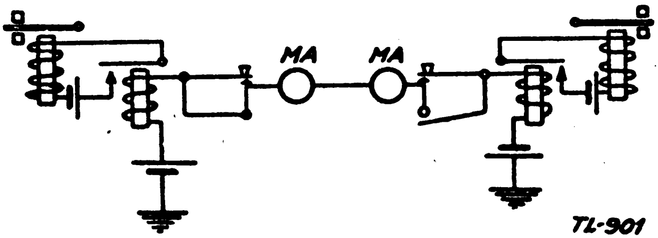

FIGURE 11.—Complete closed-circuit telegraph system.

8. Intermediate stations.—*a. Need.*—In practice, many telegraph circuits will be found to consist of more than two stations. It is customary, in such cases, to arrange the various stations involved along a continuous circuit. The circuit will therefore comprise a terminal station at each end of this circuit, with one or more intermediate stations connected into the line between them. These intermediate stations are usually referred to as "way stations."

b. Connections.—(1) *Closed circuit.*—Figure 12 shows the connections of a closed-circuit system consisting of two terminal and two intermediate stations, local-sounder circuits being omitted. Note that the intermediate stations are not grounded and have no line battery. In the event that the line breaks, stations on either

side of the break can ground their line on the side of their station toward the break and thus all stations on the same side of the break

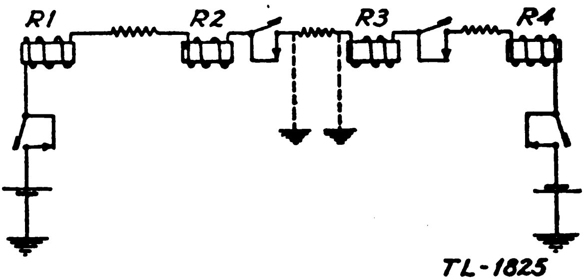

FIGURE 12.—Closed-circuit telegraph system with intermediate stations.

can continue to operate as a closed-circuit, single-battery system. For example, suppose the line to break between station *R2* and *R3*. Grounds would be established as shown in dotted lines, figure 12, resulting in stations *R1* and *R2* being able to operate with each other and, similarly, *R3* with *R4*.

(2) *Open circuit.*—Figure 13 shows the circuit of an open-circuit system consisting of two terminal and two intermediate stations. Note that each station in the system must have sufficient battery to operate the entire system, since when operating, the only battery on the line is that of the transmitting station. In the event of line breakage limited operation may be obtained as in the case of the closed-circuit system. Suppose the line breaks between *R2* and *R3*, then grounds established as shown in the dotted lines will enable the two halves of the system to function as two independent systems.

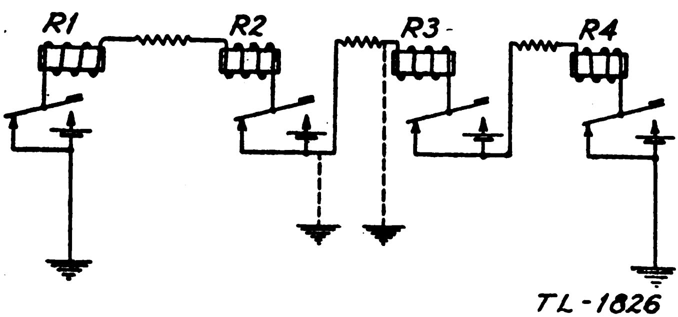

FIGURE 13.—Open-circuit system with intermediate stations.

9. Retardation and prolongation.—*a. General.*—The effect of the circuit constants upon transmission has not been considered. The wire of a telegraph circuit and the ground beneath it constitute a capacitor; at one end of this capacitor we have connected to it the battery, at the other end, the relay, which is an inductance of large

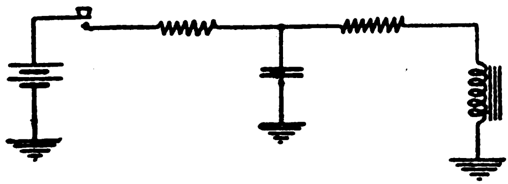
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FIGURE 14.—Telegraph line constants.

value (since it consists of many turns of wire wound upon an iron core). In order to make a very crude explanation of what happens, let us make a rough representation of the telegraph circuit by the circuit shown in figure 14.

b. Retardation.—At the instant the key is closed, there is no charge upon the capacitor and therefore no voltage between its plates. There is therefore, no voltage applied to the relay at the distant end. As current flows into the capacitor, charging it, the difference of potential between its plates rises and this difference of potential is applied to the relay at the distant end. But not until the capacitor has been pretty well charged will the voltage applied to the relay be enough to drive through its resistance enough current to operate it. It takes an appreciable time to charge a capacitor; therefore the capacity of the line to ground has acted to slow-up the signal; that is, there is a delay between the time when the operator closes his key and the time when an appreciable voltage is applied to the distant relay. Nor is this all, for we have not yet considered that the relay has inductance. We know that current through an inductance does not rise at once to its final value but builds up along a logarithmic curve. Hence, even when an appreciable voltage is applied to the relay, there is another delay before the current in the relay builds up to a value sufficient to pull up the armature and thus close the sounder circuit. This time interval between the closing of the key and the click at the beginning of a dot or dash is called the "retardation."

c. Prolongation.—When the key is opened, inductance and capacity once more come into play. The inductance of the relay tends to keep the current flowing through it until it has discharged the energy stored in it; the capacitor cannot discharge through the open key so it will discharge through the relay, the direction of its discharge current being such as will tend to hold up the armature. This time interval during which the armature holds up after the key has been opened is called "the prolongation."

10. Bias distortion.—*a. Marking bias.*—If the prolongation is equal to the retardation, transmission is affected only in that there is a slight delay. If, however, the prolongation is greater than the retardation, the signal received at the distant relay will be longer than the sent signal. Since dots and dashes would be lengthened by the same amount of time, their relative lengths at the receiving station would be adversely affected. In the case of high speed transmission, this effect may be so great as to make signals unreadable. This distortion is known as marking bias, because it lengthens the signals while shortening the spaces between signals.

b. Spacing bias.—Spacing bias is a distortion which lengthens the spaces between signals and correspondingly shortens the signals. Adjustment of a relay may, within certain limits, be made to correct for bias introduced by circuit characteristics. Consider the curve shown in figure 15 in which current in the receiving relay is plotted against time. In order to send this signal, the key was closed at point *A* on the curve. The current, due to the delaying action of the capacitance and inductance of the circuit, builds up as in the *AE* portion of the curve. The *EF* portion represents the steady state; *F* indicates the opening of the key. The decay of the current is shown by the *FJ* portion of the curve. In this curve, the rate of build-up and decay are equal, the ideal condition. This type of curve will exist when the open circuit key is used and the key allowed to make its back contact when in the spacing condition.

c. Zero bias.—Suppose that the relay is adjusted so that a current equal to one-half of the normal line current is required for its operation. The relay will then operate at a point *C* on the curve and will remain operated until a point slightly beyond *H* is reached. The difference between the current value at the operate and release points on the curve is caused by the armature travel and the residual magnetism in the core and will vary widely with different relays and different adjustments of the same relay. This will

be neglected in this discussion. The key was held on marking for the time indicated by *K* in the figure. The relay was operated for the time *O* and as may be seen from the curve *O* and *K* are equal. Since the received signal was equal to the signal sent, the circuit may be said to have zero bias.

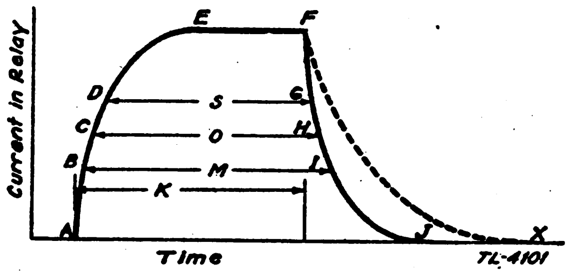

FIGURE 15.—Effect of relay biasing on signal length.

d. Bias adjustment.—If the spring on the relay has its tension increased to a point where the current required to operate the relay is as shown at point *D*, the received signal will be equal to *S*. Since *S* is smaller than *K*, the received signal is shorter than that sent, and system has spacing bias, likewise, if spring tension is decreased, the received signal will be as shown by *M*, and the system has marking bias. It may be seen that the spring tension can be used to control the bias of the received signals. The spring is sometimes referred to as biasing the relay. The spring could be replaced by another winding on the relay. Current can be placed through this winding in such a direction as to oppose the pull provided by the main winding. In this case, the extra winding is called a biasing winding and the current in this winding is called the biasing current.

e. Decay with sending key open.—In the above discussion, it was assumed that the sending key, while in the space condition, grounded the line. This does not normally exist in the closed circuit system; thus, the capacitance of the line must discharge through the receiving relay only, and the time required for the decay of the current is greater than that for the build-up. The decay will be as indicated by the dotted line *FX*. It may be seen from the figure that marking bias would result if the spring tension or the bias current were not kept at a value somewhat higher than one-half the normal line current.

11. Comparison of open- and closed-circuit systems.—*a. General.*—Before dismissing the subject of single-line telegraphy, it would be well to state the relative merits of the closed- and open-circuit systems. With one or two exceptions, these have been developed above and only a resume is needed here.

b. Advantages of closed-circuit system.—(1) *Fewer batteries.*—The closed-circuit system requires fewer batteries. Its one battery may be divided between the two ends, but the total voltage used remains the same as though it were concentrated. In the open-circuit system there must be at each station, including intermediate stations, sufficient battery to operate the entire line. In railroad dispatching where a dozen intermediate stations may be employed, the number of batteries would be prohibitive if the open-circuit system were employed.

(2) *Trouble indication.*—The closed-circuit system gives a definite indication when the circuit is opened by trouble. When the line is normal and the circuit idle, the sounder bar remains operated, thus when the line is opened the bar is returned by the spring, giving a click.

c. Advantages of open-circuit system.—(1) *Economy of power supply.*—In the closed-circuit system current flows in main-line and local circuits when no messages are being sent; in the open-circuit system current flows only while dots and dashes are being transmitted. Where the system is used steadily, this apparent disadvantage of the closed system is not great. It is also to be remembered that gravity cells operate better with fairly continuous use. The power used in a telegraph circuit costs very little in comparison with the other items of telegraph costs, and the saving of power by the open-circuit system may be wholly neutralized by the increased capital cost of so many batteries. Where the source of power is dry cells as in military field circuits, the question of dry cell replacement in the field may be a serious problem. Military lines are apt to stand idle much of the time, and, during these times, energy is being drawn from the dry cells if the closed-circuit system is used.

(2) *Leaky lines.*—The open-circuit system works better over leaky lines. This was shown in the discussion accompanying figures 9 and 10. With the hookup of figure 9, East's working margin was the same as that of any station in an open-circuit system with the same resistance and battery voltages. In wet weather, this was 30 milliamperes. Under wet weather conditions the closed-circuit

system of figure 10 had a working margin at either end of only 22.5 milliamperes. Better working margin is obtained for the open-circuit system because no leakage current flows in the receiving relay. Thus, all stations in the open-circuit system have the same working margin as has the station away from the battery in single battery closed-circuit operation.

(3) *Signal distortion.*—The open-circuit system is less subject to bias distortion than the closed-circuit system as discussed in paragraph 10*e*.

12. Questions for self-examination.—

1. What are three advantages of telegraphy?

2. What are three advantages of telegraphy over radio?

3. For what use in army field communication systems is the telegraph ideally suited?

4. Give two reasons for not putting the sounder in the main line.

5. What is meant by a ground return?

6. What are the chief advantages of the ground return?

7. What is the difference between open- and closed-circuit keys?

8. Give four disadvantages of the ground return.

9. What factors limit the distance over which telegraphy may be operated?

10. Where does leakage occur in a telegraph circuit?

11. Under what conditions is line leakage greatest?

12. Explain what is meant by "working margin."

13. An operator working over a very leaky line should observe what precaution?

14. Draw a diagram of a complete closed-circuit telegraph system consisting of three stations.

15. Draw a diagram of a complete open-circuit telegraph system of three stations.

16. What sources of power are used in central offices?

17. What source of power would be used for a field telegraph station in the army?

18. What is a protective resistance and why is it used?

19. How is the size of the protective resistance determined?

20. What properties other than resistance has a telegraph line?

21. What is the effect of line to ground capacity upon telegraph transmission?

22. What is the effect of inductance of the relay on telegraph transmission?

23. Over long leaky lines, which works better, open- or closed-circuit telegraphy?

24. What are the relative merits of open- and closed-circuit telegraphy?

25. What is meant by bias distortion?

26. What is meant by relay bias?

SECTION II

SIMPLEXED, COMPOSITED AND PHANTOMED CIRCUITS

	Paragraph
General	13
Repeating-coil simplex	14
Compositing	15
Comparison of the two methods	16
Phantom circuits	17
Combination of simplex, phantom and composite groups	18
Mutual interference in simplex and phantom groups	19
Questions for self-examination	20

13. General.—Wires may be used simultaneously for telephony and for telegraphy without interference between the two means of communication. When two wires are utilized to give one telephone and one telegraph channel, the practice is called simplexing. If the two wires provide one telephone channel and two telegraph channels, the circuit is said to be composited. Both methods will be briefly explained and their suitability for army use discussed.

14. Repeating-coil simplex.—*a. Methods.*—Two methods of simplexing exist: the repeating-coil and the bridged-impedance meth-

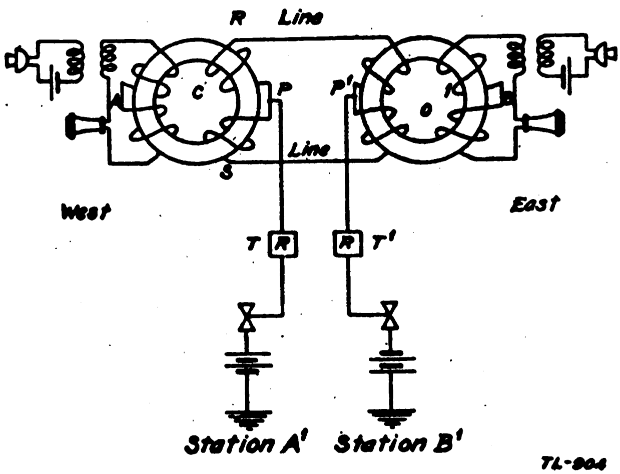

FIGURE 16.—Telephone circuit simplexed for telegraph by use of repeating coils.

ods. The repeating-coil method is used almost universally and is the one to be discussed in this text. It is illustrated in figure 16.

b. Telephone interference in telegraph.—Examination of the figure will show that if the resistances of the two wires be equal, *P* and *P′* are always at the same potential as far as the telephone currents are concerned. The two windings of the secondary of the repeating coil are identical and are connected in series; therefore when West is talking, the potential of *P* is halfway between that of *R* and that of *S*. The resistance from *R* to *P′* is the same as that from *P′* to *S*; hence the potential of *P′* is halfway between that of *R* and that of *S*. Hence *P* and *P′* may both be connected to ground and electromotive forces induced in the secondary of the repeating coil by talking into the transmitter, will not cause any current to flow from *P* to ground and thence to *P′*. So *P* and *P′* are connected together through the telegraph apparatus and ground and no telephone current flows through this telegraph circuit.

c. Telegraph interference in telephone.—Consider why the telegraph currents do not affect the telephone. Current coming from the battery at *A′* divides equally at *P*, flowing thence towards *R* and *S*. But the flux produced by the winding *PR* is equal and opposite to the flux produced by the winding *PS*; therefore no electromotive force is induced in the two windings connected to the receiver of the telephone.

d. Circuit balance.—In the explanation above, it was shown that the telegraph and telephone would not interfere with one another if the two line wires had the same resistance. If the current in a telegraph line were only steady direct current, the requirement of equal resistance in the two line wires would be all that is necessary. But since each dot or dash closes the circuit at its beginning and opens it at its end, transient currents will flow in the line. For example, closing the key causes the current to rise from zero to its final steady value; during the time the current is changing, the capacity of the line plays an important part. Hence if the simplexed circuit is to be balanced, it must be balanced not only for resistance but also for capacity. In practice, the lines used by the army in its field systems will not be balanced and a key thump will be heard in the telephone; this thump is not objectionable unless it is very strong. The telephone user, intent upon his conversation does not notice the thump any more than one notices ordinary noise during a normal conversation.

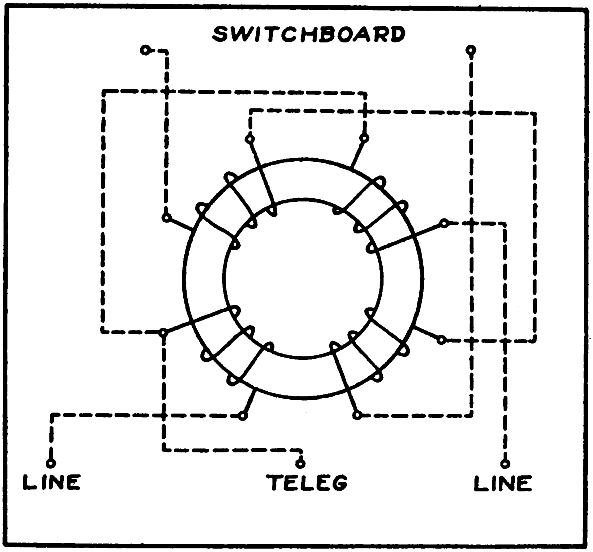

FIGURE 17.—Repeating coil C-75 or C-161 showing internal connections.

e. Connections.—The connection to the terminals of a typical repeating coil used by the army are shown in figure 17. Dotted lines represent connections which are made between the windings and the terminals; these are integral with the coil. To install the coil for a simplex, connect the switchboard or telephone to the terminals marked "Switchboard," connect the line to terminals marked "Line" and the telegraph set to the terminal marked "Teleg."

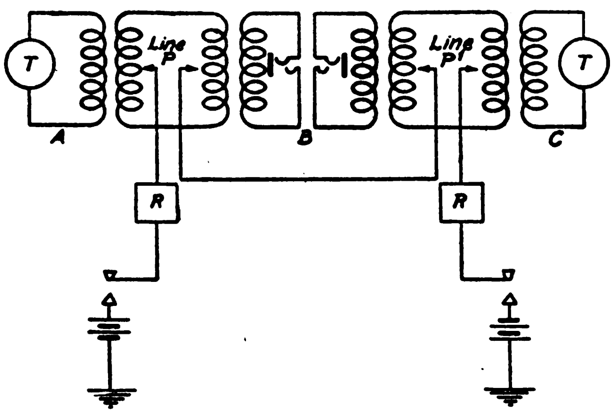

FIGURE 18.—Simplex circuit bridged around an intermediate switchboard.

Simplexing may be resorted to in getting a telegraph circuit between points *A* and *C*, where telephone circuits connect both *A* and *C* to a switchboard at *B*. The circuit is shown in figure 18. Note that two repeating coils are required at *B* and that an intermediate telegraph station could be set up at *B* by connecting the telegraph apparatus between *P* and *P′*. The repeating coils are shown schematically, without respect to the direction of the windings. This method of representation is the accepted one, where it is not desired to check the actual direction of current in the windings.

15. Compositing.—As stated at the beginning of the section the two line wires may be made to yield one telephone channel and two telegraph channels; this is called compositing. The circuit used is illustrated in figure 19. The telegraph current cannot flow into the telephones because of the capacitors and the telephone currents are little affected by the telegraph circuit because of the very high inductance placed between the line wire and ground. To improve operation, additional apparatus is connected in, but this is not essential to an understanding of the method and is therefore omitted from the figure. An intermediate station is shown in one of the telegraph circuits to illustrate the manner of connecting it.

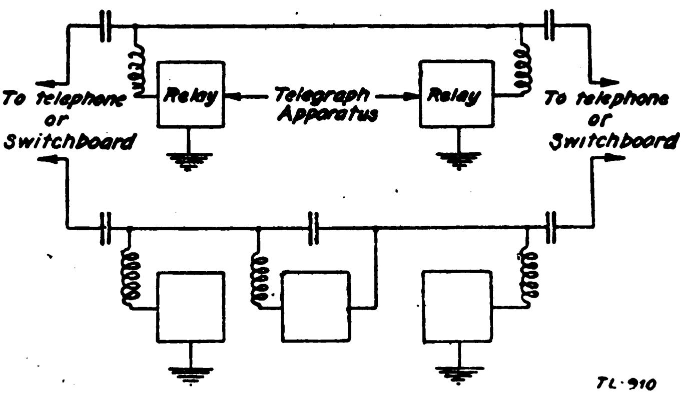

FIGURE 19.—Telephone circuit composited for telegraph. A balancing impedance, not shown, may be used in the upper line wire.

16. Comparison of the two methods.—At first glance compositing seems a more desirable method than the simplex, since it gives an additional telegraph channel. However, it has drawbacks from the viewpoint of military use. The retardation coils have high imped-

ance for voice frequency currents but the 20-cycle ringing current passes readily through them and causes the telegraph relays to chatter. Commercially, this difficulty is overcome by the use of ringing currents of higher frequency. Also the apparatus required for compositing is more complex and requires more expert installation. Finally, military practice requires so many telephone channels as minimum requirements, that if all of these be simplexed, a sufficient number of telegraph channels will have been obtained.

17. Phantom circuits.—If a metallic return for telegraph is required to eliminate difficulties encountered in a ground-return system, two simplex circuits may be used. The combination is called a phantom circuit. The phantom circuit may be used for telephone as well as for a metallic telegraph circuit. A phantom circuit is shown in figure 20. No mutual interference is noted in the system if wires *A*, *B*, *C*, *D*, and their associated equipment are balanced, that is have equal resistance, inductance, capacitance to ground and are properly transposed. Transpositions are discussed later in the text.

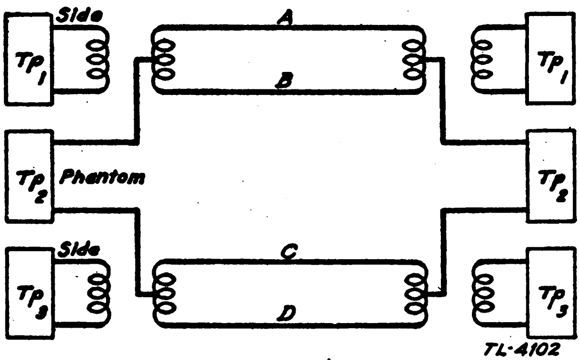

FIGURE 20.—Phantom group.

18. Combination of simplex, phantom and composite groups.—*a. Simplexed phantom group.*—Phantom circuits may in turn be simplexed for telegraph and thus three telephone and one telegraph circuit may be obtained in two pairs of wires called a phantom group. A simplexed phantom group is illustrated in figure 21. Theoretically an additional circuit could be derived from this group and another similar group but the problems involved in transposing and maintaining a balance on a system consisting of more than four wires usually make it impracticable.

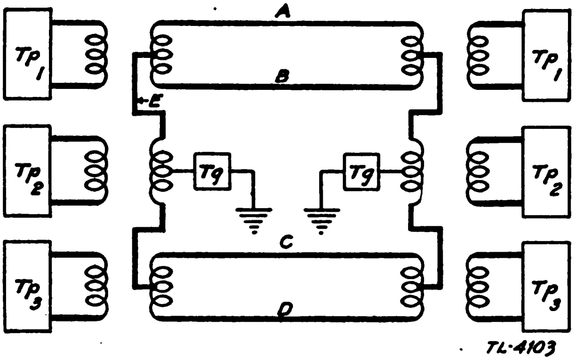

FIGURE 21.—Phantom group with phantom simplexed for telegraph.

b. Compositing of phantom.—The side circuits may be phantomed in the usual manner and the phantom composited thus providing three telephone and two telegraph channels on the four wires. Composite ringing is required for the phantom telephone circuit but normal 20-cycle ringing may be used on the side circuits.

c. Both side circuits composited.—The two side circuits may be composited and a phantom placed on the group, but composite ringing must be used on all three telephone channels. This system will provide three telephone and four telegraph channels on the four wires, the maximum number of circuits available on a group without the use of carrier. Carrier circuits will be discussed later in the text. It might at first seem that the phantom in this system could itself be simplexed or composited but it must be remembered that direct current telegraph systems cannot work through a capacitor, therefore a composited circuit cannot be re-composited.

19. Mutual interference in simplex and phantom groups.—*a.* When the wires composing a simplex or phantom group have unequal impedances, interference will result; the greater the unbalance, the greater will be the interference. Possible causes of unbalance are excessive series resistance due to poor splices, unequal leakages to ground, improper transpositions or in the case of a phantom group a cross between two wires of different pairs. It should be noted however that a short between two wires of the same pair will of course put the telephone on that pair out of service but the service on the other side circuit, the phantom and the simplex will not be adversely affected.

b. The interference resulting from any unbalance is usually more pronounced in a phantom group than in a simplex group as there are more circuits involved. Also, mutual interference between two telephone channels is more serious, due to the similarity of sound, than is the interference between telegraph and telephone.

20. Questions for self-examination.—

1. Is the repeating coil, used for simplexing, a ring-through, or nonring-through coil? Why?

2. Why should telegraph communication always supplement telephone communication in army field systems?

3. Make a diagram showing how the terminals of a repeating coil are connected when simplexing a telegraph circuit upon a telephone circuit?

4. For perfect simultaneous operation of a telegraph channel and a telephone channel over two wires, what must be true of the two wires?

5. There are two telephone lines from First Army switchboard to I Army Corps switchboard and two telephone lines from I Army Corps switchboard to 1st Division switchboard. Show by a diagram how these lines could be utilized to obtain three telephone circuits from First Army to I Army Corps, three telephone circuits from I Army Corps to 1st Division and one telegraph circuit from First Army to 1st Division, the latter channel including an intermediate telegraph station at I Army Corps.

6. How many telegraph channels may be obtained from a metallic telephone circuit by compositing?

7. Show by a diagram the principle of compositing.

8. Why is compositing usually not suitable for use by the army in the field?

9. Referring to figure 21, what is the effect of the following troubles on operation of each of the three telephone channels and the telegraph channel?

a. Short between wires *A* and *B*.
b. Open in wire *A*.
c. Ground on wire *C*.
d. Cross between wires *A* and *D*.
e. Open in wires *C* and *D*.
f. All four wires shorted together.
g. Open in wire *E*.

SECTION III

GROUNDS

	Paragraph
General	21
Variation of resistance of a ground rod	22
Multiple rods	23
Earth potentials	24
Measurement of ground resistance	25
Ground connections for field wire systems	26
Line battery	27
Questions for self-examination	28

21. General.—*a. Purpose.*—Professor Steinheil in 1837 made the discovery that the earth may be used as a portion of an electric circuit. It is used as such to a considerable extent in telegraphy. Its use in telephone communication introduces noise in the circuits caused by induction from neighboring power lines and causes cross-talk between adjacent circuits. It is therefore little used in telephone communication except to drain off lightning and other static disturbances.

b. Connections.—Connections to the earth are usually called grounds and may be obtained by connection to buried pipe systems, buried plates, buried wire or driven pipes or rods. Where pipe systems are not available, driven rods are the usual method because of the ease of installation.

c. Resistance of ground return path.—It might seem at first thought that the resistance of the ground return path would be fairly high. It is true that the specific resistance of the earth is very high in comparision with that of a metallic conductor, but the cross sectional area of the path is very large, therefore the resistance between any two ground rods is relatively low if a good connection is obtained. Since the cross sectional area of the path is smallest near the electrode, the greatest share of the ground resistance is here; therefore, good conductivity of the soil near the electrode is essential.

d. Factors affecting resistance of connection.—The resistance of a ground connection may vary from a fraction of an ohm to several thousand ohms depending on a number of factors. Some of these factors are: the nature of the soil, moisture content of the soil, the physical dimensions of the connection, the material of the connection and the effect of the past corrosion and electrolytic action.

22. Variation of resistance of a ground rod.—*a. Depth.*—The resistance of a ground rod decreases with increase in depth quite rapidly for the first few feet but, except in the case of unusually high resistivity of the soil in the upper layers, little advantage is gained by the use of rods longer than five feet. It is often found, however, that moisture content of the soil is higher at the lower levels. In freezing weather, ground rods should be long enough to reach below the frost line.

b. Rod diameter.—When the ratio of the length of a ground rod to its diameter is large, as it usually is, only slight advantage is gained by increasing the diameter of the rod. Diameter of the rod should therefore only be large enough to permit easy installation.

c. Electrode material.—Experimental work has shown that the metal used for electrodes is unimportant except as to its resistance to corrosion. Copper clad rods are probably the least subject to corrosion of any of the types in common use. Iron rods, plain and galvanized, are quite extensively used and give good service. The iron oxide which forms on plain iron rods is not detrimental as its conductivity is better than the surrounding soil.

d. Soil conditions.—The features of soil which make it advantageous for grounding are the presence of moisture and the concentration of salts dissolved in this moisture. Grounds obtained by rods of the same length in different types of soils may vary from a few to several thousand ohms. The following list arranges soils of various types in order of ascending specific resistance: wet soil, clay or loam, clay or loam with sand and gravel, wet sand, dry sand, gravel and stones.

e. Chemical treatment.—Where high ground resistances are encountered due to lack of salts in the soil, these resistances may be reduced by placing salt in an excavation around the top of the rod, then wetting thoroughly. Salts most commonly used are sodium chloride, calcium chloride, sodium nitrate and copper sulphate.

23. Multiple rods.—It has been found from various tests that 90 percent of the total potential drop around a ground rod generally occurs within 6 to 10 feet of the rod, depending on the length of the rod and the nature of the soil. It may be considered then that the effective electrode consists of a volume of the earth surrounding the rod. When paralleling two or more rods together, it is desirable to space them so that the effective electrodes do not overlap to any considerable extent. Five-foot rods should in general be spaced not closer than 8 feet and preferably 15 feet apart. Longer rods should have spacing at least as great as their length. Even with this spacing, the actual resistance of parallel combination will be higher than that computed from their separate resistances. In general, the greatest benefit is obtained from paralleling grounds when the specific resistance of the soil is high.

24. Earth potentials.—It will usually be found that between any two ground rods placed some distance apart that a potential exists. This potential will in most cases be fluctuating. It arises from various natural and artificial currents flowing in the earth due to power systems, street railway systems, Aurora Borealis, lightning etc. Potentials will, at times, be large enough to interfere seriously with telegraph communication and may be, in some cases, high enough to be dangerous to life, particularly in the case of long commercial lines.

25. Measurement of ground resistance.—Accurate means of determination of ground resistances are difficult and in many cases meaningless because of the wide changes which may take place after the determination has been made. Determinations under conditions which simulate actual use are desirable when practicable. A useful field means of determining whether a ground is suitable for use on a teletypewriter circuit is to set up a teletypewriter for local operation between two ground rods spaced about thirty feet apart. Have the line rheostat adjusted to a value at least as great as the resistance of the line on which the teletypewriter will be placed. If satisfactory local operation is obtained, connect the two rods together and use the combination for the ground connection for normal use.

26. Ground connections for field wire systems.—In the usual case in which a ground return circuit is used, a low-resistance ground connection is necessary for each terminal station not only to insure

sufficient operating current, but also to prevent interference with neighboring telegraph circuits. It is almost always possible to obtain a good ground by proceeding as follows:

a. Drive a ground rod into the ground where it is moist. Usually, except in very dry weather, the ground near the roots of a shrub or tree is moist. If only dry ground is available, wet it thoroughly and pack it down around the rod.

b. Use a separate ground for each telegraph set or other equipment and keep separate grounds at least 15 feet apart.

c. Use two or more ground rods at least 15 feet apart connected together if one ground rod will not suffice.

d. Keep the wire leading from the ground rod to the set as short as possible, but do not hesitate to use a wire several hundred yards long if necessary to reach moist ground, such as a stream bed.

27. Line battery.—In field telegraph systems, high resistance grounds may be partially compensated for by use of additional line battery when means to lower the resistance have failed. Direct earth potentials may, in some cases, cause faulty telegraph operation. If this is suspected, reverse the line batteries so that the earth potential aids rather than opposes the voltage of the batteries.

28. Questions for self-examination.—

1. What is the importance of having low resistance ground connections in communication systems?

2. How does the resistance of a ground connection vary with each of the following factors? Why?

(a) Moisture content of the soil.
(b) Salts in the soil.
(c) Material in the ground rod.
(d) Length of the ground rod.
(e) Diameter of the ground rod.

3. Describe a method of determining if the resistance of a ground is low enough for satisfactory operation.

4. What is the purpose of using multiple ground rods? What spacing should be used for multiple rods?

Section IV

TELEGRAPH RELAYS

	Paragraph
Simple neutral relay	29
Differential neutral relay	30
Differential polar relay	31
Polar relay without permanent magnet	32
215-type Western Electric relay	33
41-type Western Union relay	34
Questions for self-examination	35

29. Simple neutral relay.—The relay described in paragraph 3 which has been used in the circuits considered so far in this text may be said to be a simple neutral relay. It is called simple because it has only one winding with two terminals. It is called neutral because it will be operated by a current flowing in either direction through this winding.

30. Differential neutral relay.—A differential relay is one which has two windings, so connected that the flux from one winding opposes that produced by the other and thus the relay is operated by the difference between the current in the two windings. Such a relay is illustrated schematically in figure 22. In this figure the

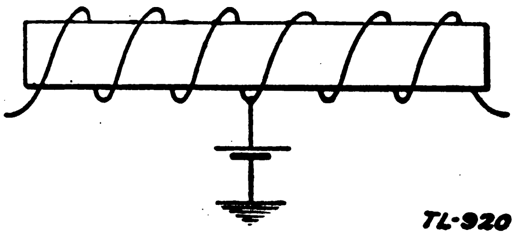

Figure 22.—Differentially-connected relay winding.

two windings have a common terminal which is shown connected to the battery. In practice all terminals are usually brought out separately in order to provide flexibility in the method of con-

nection. If the two windings are connected in series with the battery, their fluxes are in the same direction and the relay may be used as a simple relay; if the two windings are connected in series and the battery applied to the common connection as shown in the figure, the relay is a differential one, since the fluxes now oppose. The windings may be used in parallel if desired.

31. Differential polar relay.—*a. Definition.*—A polar relay is one which will move its armature in one direction when current is passed through its winding in one direction and which reverses the direction of movement when the current is reversed. Such a relay when adjusted for zero bias will, with no current in its winding, remain in either position when operated manually, or remain in the mid-position, depending on the type of relay.

b. Operation.—The principle of the polar relay may be understood with the aid of figure 23. A U-shaped permanent magnet, magnetized so as to have two equal south poles as indicated in (a), has pivoted at its midpoint a soft-iron armature, which projects upward and plays between two pole pieces attached to the ends of the magnet, as shown in (b). The upper end of the armature is then a north magnetic pole and it is evident that the armature will remain against whichever pole piece it is placed, since no spring is used. A winding surrounds each pole piece and the two windings are connected in series. If the current is in the direction shown in (c), the field due to the current will weaken the magnetism of the left-hand pole piece and strengthen that of the right-hand one. Consequently, the armature, a north pole, will be drawn towards the stronger south pole. If the current were reversed, the armature would be pulled back towards the left.

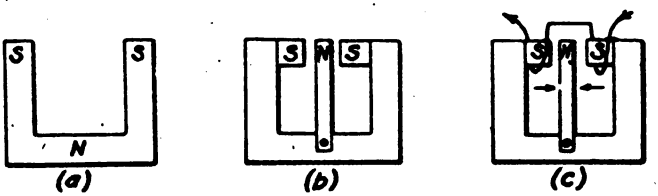

FIGURE 23.—Construction of a polar relay with permanent magnet core.

c. Connections.—Polar relays may also be wound differentially. Each winding has the same number of turns about each pole piece. A differentially wound polar relay is represented schematically

in figure 24. If equal currents flow from *P* through the windings, the pole strengths will be unaffected and the armature will remain wherever it was before the currents commenced to flow. However, if current enters at *R* and leaves at *P* and *S*, the two south poles will be unequal in strength; the armature will be drawn to the left.

32. Polar relay without permanent magnet.—A relay with the same general characteristics as that described in paragraph 31 can be made by adding a biasing winding to a neutral relay. The current in this biasing winding is adjusted so that the magnetic attraction for the armature balances the pull exerted by the spring. When the current in the main windings is in the direction to aid the flux produced by the biasing windings the armature is pulled to the mark contact but when the flux produced by the main winding opposes that of the biasing winding the armature moves to space. It should be noted, however, that if the flux produced by the main winding opposes and is equal to that in the biasing winding, the total flux is zero and an increase of current in the main winding will pull the relay to mark even though the current is in the spacing direction. This action takes place when the flux produced by the main winding is slightly greater than twice that of the biasing winding. Difficulty of this sort can be avoided by keeping the biasing current and the corresponding spring tension high, thus preventing the total flux from passing through zero.

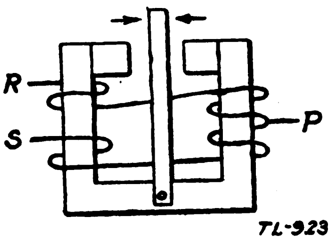

FIGURE 24.—Differentially-wound polar relay.

33. 215-Type Western Electric relay.—*a. Description.*—A type of polar relay in common use commercially is the Western Electric type 215. The essential features of this relay are shown in figure 25. The magnet is a permanent magnet made of hard steel. The two yokes, the reed and the pole pieces are made of permalloy which is a special alloy that conducts magnetic lines of force in the same manner that soft iron does. The reed is a thin strip

clamped at its base. It is the relay armature. It can be flexed from the marking to the spacing contact but due to the fact that it is a spring it stands midway between the pole pieces when no current flows in the winding.

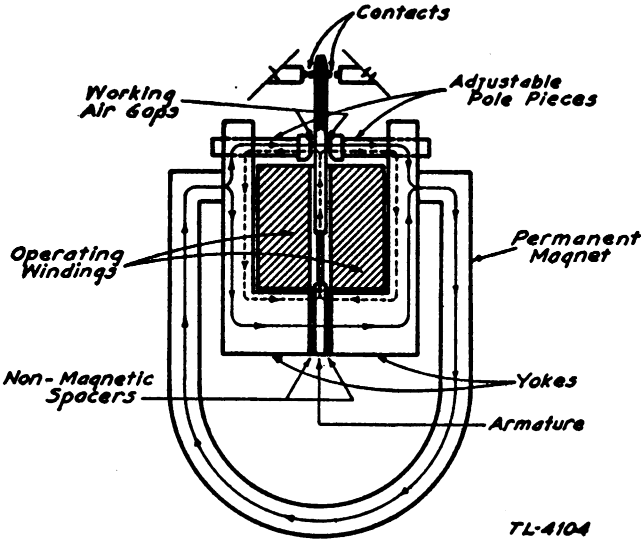

FIGURE 25.—Western Electric Co. 215-type relay.

b. Flux.—Due to the permanent magnet, lines of force flow as shown by the dotted arrows. No flux flows in the reed because the upper and lower ends are at the same magnetic potential. If a current of one polarity flows in the windings it will cause flux as shown by the dotted arrows. No flux flows in the reed because the the right pole piece and opposes that in the left. The reed thus moves to the right. A current in the opposite direction in the winding will move the reed to the left. One contact may be designated mark and the other space, the marking and spacing contacts being closed on the two direction of currents in the windings. The 215–A relay has two equal windings; others of the same general construction may have different winding arrangements.

c. Use.—The sensitivity and speed of operation of this relay make it suitable for use on teletypewriter circuits and it has a wide application in commercial printers and repeaters. It is designed for use on polar systems but can be used in neutral systems if a biasing current is supplied.

34. 41-Type Western Union relay.—The Western Union 41-type relay is used in the line unit *BE–77* which is turn a part of the teletypewriter *EE–97*. This relay is of the neutral type but has two equal windings and may be used for polar operation as shown in paragraph 32. The resistance of each winding is about 100 ohms. The relay is of the plug-in type and is biased by a spring under control of a thumb screw at the end of the case. It has both a front and back contact for use when polar operation is desired.

35. Questions for self-examination.—

1. What is meant by a neutral relay?
2. What is a differential relay?
3. What is a polar relay?
4. How may a neutral relay be arranged for polar operation?
5. How may a polar relay be arranged for neutral operation?
6. What kind of relay contains a permanent magnet?
7. How many windings are necessary on a neutral relay if it is to be used as a polar differential relay?

Section V

DUPLEX TELEGRAPHY

	Paragraph
Meaning of duplex	36
Single-current differential duplex	37
Double-current differential duplex	38
Bridge duplex	39
Short-line duplex	40
Questions for self-examination	41

36. Meaning of duplex.—That method of telegraphy by which messages are simultaneously sent and received over one circuit, is called duplex telegraphy. A sending operator and a receiving opertor are required at each end. Several methods of duplex telegraphy exist; the single-current differential, the double-current differential, the single-current bridge, the double-current bridge, and the Morris short-line duplexes. For reasons to be pointed out later, the double-current systems are preferred in actual use, but to make their understanding easier, the single-current differential duplex will be described first.

37. Single-current differential duplex.—*a. General.*—In order to receive a message at the same time that one is being sent from the station, the relay must not respond to the key of the home sending operator but must respond to the key of the sending operator at the distant station. To accomplish this, the relay used must be of the differential type. The key used is an open-circuit telegraph key, the back contact being connected to ground through a resistance. The type of relay used in single-current differential duplex telegraphy is illustrated schematically in figure 22. The same differential effect is given by the relay of figure 26 since the current, flowing from the battery, divides at the midpoint of the winding and current flows around the core in opposite directions from that point.

b. Operation.—(1) The circuit in which this relay is used is shown in figure 26. The line resistance has been assumed to be 1550 ohms; the resistance of each winding of the relay has been assumed to be 400 ohms, the normal practice; the sum of the protective

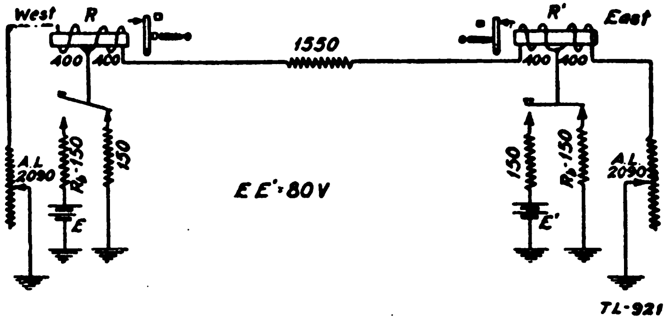

FIGURE 26.—Single-current differential duplex system.

resistance and the internal resistance of the battery is assumed to be 150 ohms; the foregoing resistances determine the other resistances which must be used, as will be seen from the explanation below. *AL* stands for "artificial line"; it is merely a resistance, whose value is determined by the resistances assumed above. The resistance between the back contact of the key and ground must be the same as the resistance between the front contact and ground. In the figure, neither operator is sending and, therefore, both keys are on the back contacts. No current flows in the line or through the relays; neither armature is pulled up.

(2) Now suppose East and West start sending simultaneously, East to send a dot and West to send a dash. Both keys are on the front contacts. In the circuit from ground, through West's battery, the right hand winding of West's relay, the line, the left hand winding of East's relay, through East's battery back to ground, we have two equal batteries connected opposing one another. Therefore no current flows in the circuit just traced. There is a path from ground, through West's battery, the left hand winding of West's relay, and the artificial line back to ground. A current of 30 milliamperes flows in this circuit, energizing the relay and pulling up the armature of West's relay. A similar path exists at East and East's relay armature is also pulled up.

(3) Since East is sending a dot, he releases his key before West does his. Consider whether the armatures operate properly. East has released his key which now rests on the back contact; hence East's battery is out of the circuit. It is now necessary to determine what current flows because of West's battery. Starting from ground, current flows through West's battery up to the midpoint of West's

relay, where it divides. If it divides equally at this point, the flux produced by one winding will be equal and opposite to the flux produced by the other and the relay will not be energized. The armature will fall back (which it should do, since East has just finished sending a dot). The current will divide equally at the midpoint if the resistances to the left and right of the midpoint are equal. The resistance on the right is:

$$400+1550+400+\frac{150\times(400+2090)}{150+400+2090}=2490 \text{ ohms (approx.)}.$$

The resistance on the left of the midpoint is also 2490 ohms. Therefore, the current does divide equally and West's relay is not energized. The current which flows through East's relay is all in the the same direction; the fluxes produced add together, and East's relay is energized. It should be, because West is still sending his dash. It is seen from the above that the relay at each station is properly actuated, regardless of the position of the key at that station.

(4) Note that the artificial line must be of such resistance as will cause the current to divide equally at the midpoint of the home relay when the distant key is on the back contact. The necessary value of the artificial line resistance may be computed, knowing all the other resistances in the circuit. However, it is much simpler and easier to adjust the artificial line until the home relay is not actuated when the home key is depressed. The operation of all duplex systems is improved by making the artificial line conform more closely to the characteristics of the actual line by adding capacity to the former. The needed capacity is not computed but is arrived at by adjustment.

38. Double-current differential duplex.—*a. Reasons for use of double current.*—Certain inherent disadvantages of single-current telegraphy lead to the use of double-current telegraphy. The principal disadvantages are: spacing is accomplished by interrupting the current or by neutralizing its magnetic effects; due to residual magnetism of the relay core, the action of the armature will be uncertain when the current interrupted is weak; induction from neighboring circuits may cause the armature to pull up during a space. In double-current telegraphy, the back contact of the key is connected to ground through a battery which is poled opposite to that connected to the front contact. This requires the use of two batteries

or generators at each station or the use of a single battery with a pole changer. Since current always flows in the double-current system, the method is more positive in its action. The beneficial effect of a split battery upon leakage is also gained. The slowing up of operation, due to the capacity, is overcome because the charge, instead of having to leak off when the key changes contacts, is neutralized by current from the oppositely poled battery.

b. *Operation.*—(1) *Both spacing.*—The circuit of the double-current differential duplex is shown in figure 27. Assume the resistances to be as shown; they are the same as those of figure 26 and are arrived at in the same way as in that case. If no operator is sending both keys are on the back contacts. Because of

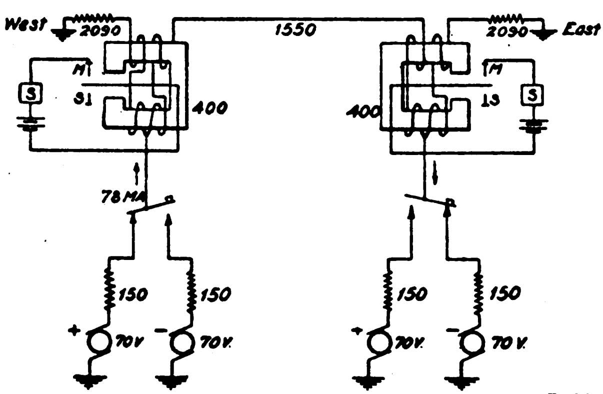

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Figure 27.—Double-current differential duplex system.

the equal batteries opposing one another no current flows in the line. Current flows from each battery through the outer relay winding and artificial line to ground. The direction of the flux is such as to make the lower pole a stronger south pole than the upper and the armature is drawn against the space contact (marked *S* in the figure). This is an idle contact, connected to nothing, whereas the mark contact, *M*, closes the sounder circuit when in contact with the armature.

(2) *Both marking.*—Assume that East and West start sending simultaneously, East sending a dot and West sending a dash. It is customary to connect the two generators as shown in figure 27 so that when spacing, positive battery is connected to the line by the key touching the back contact, and negative battery is put on the

line when marking. Both operators, by depressing their keys, connect negative battery to the line. Since the two batteries oppose and are of equal voltage, no current flows in the line or the right-hand winding of West's relay or the left-hand winding of East's relay. About 27 milliamperes flows through the left-hand winding of West's relay; the direction of this current is such as to make the pole marked *M* stronger and that marked *S* weaker. Hence, the armature, being a north pole, is pulled towards *M*, closing the sounder circuit and beginning the dot which East is sending. A similar current, flowing through the right-hand winding of East's relay, causes the armature to move against the contact *M*, closing the sounder circuit and beginning the dash which West is sending.

(3) *One marking, one spacing.*—A fraction of a second later, East completes the dot and lets up on his key, thus connecting positive battery to the line at his end. West's key is still down, connecting negative battery to the line at his end. Finding the values of the currents in the different parts of the circuit is a problem which must be solved by the use of Kirchoff's laws; the solution is tedious and will not be entered into. A current of 74 milliamperes flows from East's battery to the midpoint of his relay, where it divides, 50 milliamperes going to the line and 24 milliamperes going to the artificial line. The 50 milliamperes in the line is joined at the midpoint of West's relay by a current of 24 milliamperes flowing from ground through West's artificial line: 74 milliamperes flows from the midpoint through West's battery to ground. In East's relay, the current flowing in the left-hand winding is greater than that in the right-hand winding and, therefore, controls the polarity; the pole marked *M* is more strongly south. This pole holds the armature up aginst the contact *M*, keeping the sounder circuit closed. This is what it should do, since West is still sending a dash. In West's relay, the current in the right-hand winding is the greater and its direction is such as to make the pole marked *S* more strongly south. Therefore, the armature of West's relay moves over against the contact *S*, breaking the sounder circuit and thus completing the dot which East had just finished sending.

(4) *Keys in intermediate position.*—In the manipulation of the keys in both single- and double-current differential duplexes, there are constantly recurring intervals during which the key is in an intermediate position, touching neither front nor back contact. This condition is apt to cause confusion of signals, especially on leaky

lines. The difficulty is overcome by the use of a continuity preserving transmitter. This simple instrument will not be explained in this text.

39. Bridge duplex.—*a. Principle.*—The principle of the Wheatstone bridge is applied in another method of duplex telegraphy, called the bridge duplex. As seen from either end, the circuit is a balanced bridge in which the nearer relay is connected where the galvanometer would normally be. The relay used is a polar relay. (The relay may be the same type used for double-current differential duplex but the windings are connected in series instead of differentially.) To facilitate understanding of the operation of the double-current bridge duplex, a simplified diagram of a typical circuit is shown in figure 28. *P* and *P′* are the relays, represented in the figure as simple resistances.

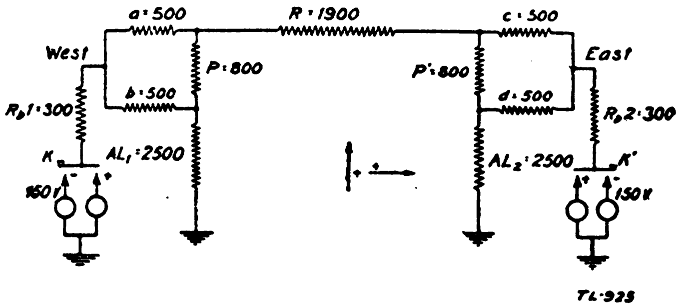

FIGURE 28.—Simplified diagram of bridge duplex system.

b. Operation.—(1) *Both spacing.*—With neither East nor West sending, the keys rest on the back contacts, connecting positive battery to the line at each end. No current flows in *R,* since equal batteries are connected opposing each other. Current flows from West's battery through R_b1: this current divides, part flowing through *b* to AL_1, the remainder flowing through *a* and *P* to AL_1. This current through *P* is directed down and the relay, which is *P*, is so connected that current down causes the armature to pull over against the space contact. Similarly, it will be seen that current flows down through *P′*, East's relay, causing its armature to rest against the space contact.

(2) *Both marking.*—Now suppose East and West start sending simultaneously, East sending a dot and West sending a dash. Both keys are on the front contacts, thus connecting negative battery to

the circuit at either end. Again no current flows in *R*. But current flows from ground through AL_1, dividing, part going through *b* to R_b1, and part flowing through *P* and *a* to R_b1. The current through *P* is now up and if current directed downwards through the relay *P* caused the armature to rest against the space contact, this upward current will pull the armature over against the mark contact, closing the sounder circuit and beginning the dot which East is sending. Similar analysis will show that the current through East's relay, *P'*, is also directed upward, closing his sounder circuit and beginning the dash which West is sending.

(3) *One marking, one spacing.*—When East finishes sending the dot, his key rests on the back contact, connecting positive battery to the circuit at his end; West's key is still on the front contact and negative battery is still connected to the circuit at his end. Solution of the circuit problem by Kirchoff's laws shows that current flows down through *P* and up through *P'*. This will cause West's relay to pull over against the space contact, opening his sounder circuit and completing the dot which East sent. Since the current is up through East's relay, *P'*, the armature will remain against the mark contact, keeping his sounder circuit closed. The sounder circuit should be closed since West has not completed sending the dash.

c. Complete circuit.—(1) *Equipment.*—Figure 29 shows the circuit from which the simplified diagram of figure 28 was made. The four 500-ohm resistances, *a, b, c,* and *d,* are the four windings of two retardation coils. The 2500-ohm resistances are the artificial lines: 300 ohms is the protective resistance in series with each generator. The 800-ohm resistances are the polar relays. In figure 29, there is added a piece of equipment not previously discussed. This

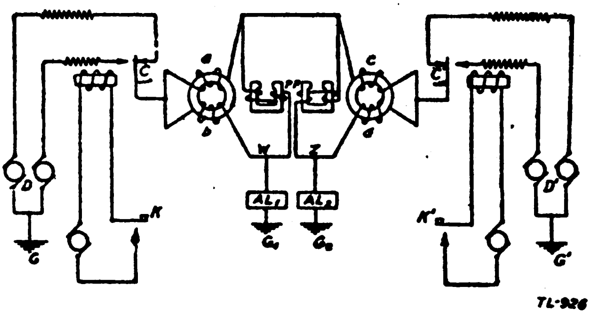

FIGURE 29.—Bridge duplex system.

is the pole changer, by which marking and spacing is accomplished instead of by connecting the generators directly to the key contacts. It is not believed that the operation of the pole changer requires any explanation.

(2) *Reason for use of retardation coils.*—Each 500–ohm winding of the coil possesses considerable inductance, and consequently, a current coming over the line wire meets at first with great opposition in traversing the retardation coil winding, because of the counter electromotive force of self-induction which is developed in it. This electromotive force is in such direction as to assist in the rapid growth of current in the polar relay to a value momentarily greater than the steady value. This initial pulse of current through the relay causes its armature to be moved from contact to contact with great rapidity. The retardation coils do not hinder outgoing currents very much because equal currents pass through the winding of the coil differentially, and the magnetism developed in the core by one winding is neutralized by that developed by the other. Hence, the coils for this condition are noninductive.

40. Short-line duplex.—*a. Use.*—The great advantages of the short-line duplex lie in the fact that one of the stations requires very little equipment, no main-line generators, and a battery only sufficiently large to actuate a sounder. It is possible therefore to duplex a line from a large central station to a station at which it is uneconomical to maintain the costly generators required for the other types of duplex. This characteristic of the short-line duplex renders it very useful to the army, when it is desirable to work duplex with a large central station from a station in the field.

b. Circuit and operation.—(1) *Equipment.*—The circuit used is shown in figure 30. The large central station is West and the field station is East. The relay at West is called a differential neutral relay. (it is differentially wound but it is not polar; and excess of current in one winding over that in the other causes the armature to pull up regardless of the direction of the current). East's relay is an ordinary polar relay. The resistance of the artificial line, *AL*, is the same as the resistance from x to the ground at G'. The resistance of rheostat r is so adjusted that three times as much current flows through the line and East's relay when the key, K', is depressed as when K' is opened.

(2) *Both spacing.*—If both keys are open, current flows from West's generator and divides equally at the midpoint of West's relay, since the resistance to ground from that point is the same through either path. Hence, West's relay is not energized, there being no resultant flux in the core. The direction of the current through the line and East's relay is such as to make the armature of the polar relay rest against the idle or space contact. It is seen that when both keys are open, both relays space, as they should.

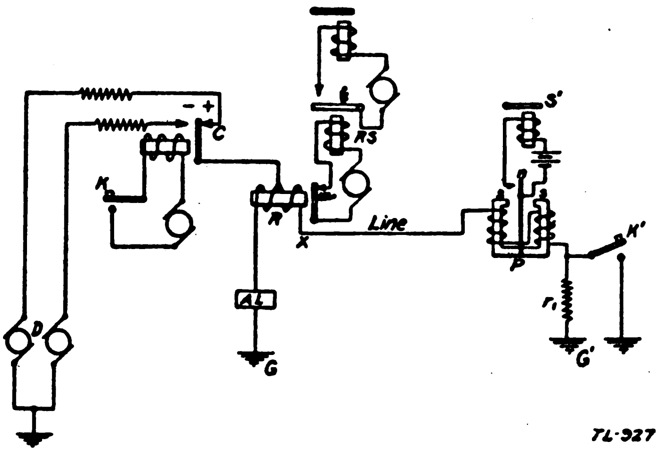

FIGURE 30.—Short line duplex system.

(3) *Both marking.*—If both keys are depressed, r_1 is shorted out and three times as much current flows in the right-hand winding of West's relay as in the left-hand winding. This excess of current in one winding energizes the relay and West's relay pulls its armature up to the marking contact. Depressing *K* has changed the direction of current through East's relay since negative generator is now connected to the line. The reversal of current in the polar relay causes its armature to move over to the marking contact.

(4) *One marking, one spacing.*—(a) Now suppose *K* to be depressed and *K'* to be open. Again current divides equally at the midpoint of West's relay and his relay is not actuated. The current through East's relay flows from ground to line and as this is a polar relay, the armature rests against the marking contact.

(b) If *K'* be depressed and *K* open, r_1 is out of the circuit. The direction of current through East's relay is such as to hold the armature on the idle or space contact. But three times as much

current flows in the right-hand winding of West's relay as in the left-hand winding; his relay is, therefore, actuated, pulling its armature up to the marking contact.

(5) *Repeating sounder.*—The repeating sounder *RS* must be used to eliminate false signals when *K* changes contacts while *K'* is being held down. When this occurs, the magnetization of *R* is reversed and therefore passes through zero. The zero magnetization allows the relay armature to fall back, closing the repeating sounder circuit. But the magnetization passes so quickly through zero that the current in the repeating sounder circuit does not have time to build up to a sufficient value to drag down the armature of the repeating sounder. Before the current in *RS* builds up, the magnetization of *R* is enough to pull its armature up and break the repeating sounder circuit again. Had the sounder been actuated directly by the armature of *R*, this delay could not have occurred and false clicks would have resulted. To aid in the operation, *RS* employs a heavy armature.

41. Questions for self-examination.—

1. What is duplex telegraphy?

2. What is the object of the artificial line?

3. What are the disadvantages of single-current duplexes?

4. Make a complete circuit diagram of a double-current differential duplex system of two stations.

5. What type of relay is used in a double-current bridge duplex?

6. What is the object of the retardation coils of the bridge duplex?

7 .What are the advantages of the short-line duplex?

8. Why must a repeating sounder be used?

SECTION VI

TELETYPEWRITER MACHINES

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42. Purpose.—The teletypewriter is a machine operated type of telegraph communication. It is designed so that it can consistently maintain a high speed of operation. It may be used for telegraph communication from division headquarters back through the higher units, or between other points where a large amount of telegraph traffic is handled. One or more receiving stations may be operated from the same transmitter, producing a printed or typed copy of the message at each receiving station simultaneously.

43. Description.—Normally the teletypewriter installation consists of a keyboard similar to a standard typewriter keyboard and a typing or printing mechanism designed to print received messages either on a page as is done with typewriters or on a tape in the manner of stock quotation tickers. The page teletypewriter may type the message on separate sheets of paper or it may be equipped with a roll of paper from which the sheets may be torn at will. Several copies of the message may be made simultaneously with reception by inserting carbon paper between the sheets or in the roll of paper. At certain stations where receiving service only is required the keyboard may be omitted. On the other hand when a large volume of outgoing traffic is to be handled, a more elaborate sending mechanism in which messages are first recorded on a per-

forated tape and then run through an automatic transmitter may be used. Also at certain stations special characters may be placed on the keyboard and typing unit for the transmission of special information such as weather reports.

44. Operation.—In this section no attempt will be made to study in detail the design features or method of operation of each of the several types of teletypewriters, but consideration will be given to some of the general features applicable to all of them. Teletypewriter operation of telegraph service differs essentially from manual operation only in the substitution of sending and receiving machines (usually both within the same cover) for keys and sounders. Therefore, in the following discussion of the factors involved, circuits and examples of operation are taken from the manual system when the same factors apply to the teletypewriter system in order to simplify the explanation.

a. Code and signal composition.—(1) The signaling code used is not the Morse code of manual operation but a special one in which each letter or signal is made up of five units or elements of equal length. These units or elements are known as marking or spacing impulses. Marking impulses or signals are those impulses which operate the selector magnets of the printing mechanism of the teletypewriter. Spacing impulses or signals, which are the same length as the marking impulses, are those impulses that do not operate the selector magnets in the receiving machine. Two more impulses common to all code groups are necessary, and complete the code group for any letter, figure, character, or function, making a total of seven impulses to be transmitted. One of these impulses is a spacing impulse and is the first impulse sent, being used to set the receiving machine in motion and in readiness to receive the remainder of the code group. This impulse is the same length as the code impulses following it and is known as the start impulse. The other impulse, a marking impulse, is always the last impulse sent for each code group, and is used to return the receiving machine to a position of readiness to receive the start impulse just preceding the next code group. It is 1.42 times as long as any one of the other impulses and is known as the stop impulse because it stops the receiving machine in order to maintain synchronism. This will be explained more fully later.

(2) As illustrated in figure 31, the code provides for the letters of the alphabet, the numerals and several miscellaneous symbols

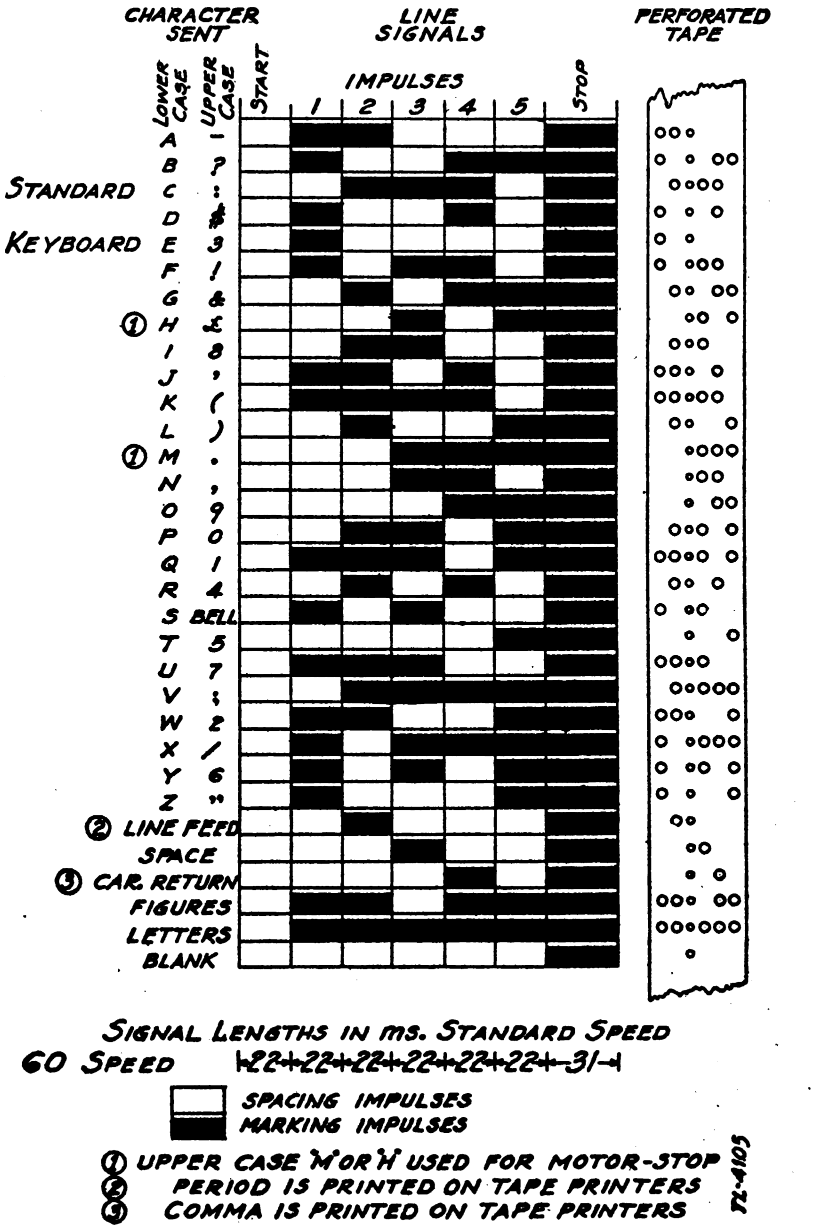

FIGURE 31.—Five unit teletypewriter code.

in common use or especially desired, as well as the special functions that the machines must perform, such as line feed, carriage return, and miscellaneous switching and signaling features. The provisions are made by using the 32 combinations that the 5-impulse code permit, including a "letters-shift" and "figures-shift" feature. The machine must then be so designed that when a certain letter key is operated at the sending machine, the marking and spacing signals corresponding to the code for that letter are sent out on the line; and when this signal combination comes in at the receiving machine, the corresponding type bar is selected and operated to print the letter. The code is known as the five unit permutation code and is sometimes called the five-impulse start-stop code. A six-unit code, which allows 64 different combinations, is used where it is necessary to transmit capitals, small letters, numerals, and punctuation or other marks or symbols for telegraph type-setting.

(3) Assuming some means is provided for the transmission of the desired impulses for a given code there remain two additional essential features for which provision must be made. First, and of vital importance, the sending and receiving machines must be kept in synchronism. That is, there must be a definite and constant time relationship between the operation of the two machines so that when No. 1 impulse is being transmitted from the sending machine, the receiving machine will be at the proper point in its operation to receive No. 1 impulse, and so on. Second, there must be a means of selecting the desired character in accordance with the incoming current impulses; this is sometimes effected by electromagnets but in recent machines is effected by purely mechanical means.

45. **Synchronism.**—Teletypewriters are synchronized by means of the start-stop system. The fundamental idea of this system is that the machines, instead of running continuously, shall be stopped after the transmission of each series of five impulses comprising the signal for one character. This insures that the two machines will be in exact synchronism at the beginning of every character; in other words, it corrects any existing timing differences so frequently that errors are not likely to occur. It requires, however, that two synchronizing current impulses be transmitted for each character in addition to the five selecting code impulses, a feature which necessarily extends the time required for the transmission of each character. There are several different designs of the controlling apparatus for start-stop systems. The oldest and perhaps

the most easily understood of these consist of a pair of commutators, the segments of which are connected to the line and the electrical elements of the sending and receiving machines, and are connected together periodically in a definite order by brushes rotating in synchronism and stopping at the end of each revolution. A simplified diagram of the sending and receiving faces of a pair of these commutator devices, known as distributors, is given in figure 32.

a. Selecting operation.—Figure 32 shows the circuit in the normal condition ready for the transmission of a character. Battery is supplied from ground at the sending station through the start-stop contact, center segment, and line relay of the sending station to the line and through the line relay to ground. Also a local battery at the receiving station supplies current through the mark contact of the line relay to the center segment of the receiving distributor. Since the circuit for the start magnet is held open at the line relay space contact the distributor arm is held stationary. These arms are connected to the motor through a friction clutch. When a keyboard key is depressed at the sending station the first thing that happens is that a set of sending contacts are closed to correspond to the code of the letter to be transmitted. Then the start-stop contact is opened momentarily. This opening of the start-stop contact opens the line circuit causing the line relays to release to the spacing contact. This closes the circuit at each station for the start magnets so that their latches are lifted and the distributor arms permitted to rotate. Since the motors are adjusted to approximately the same speed the distributor arms will remain in very close synchronism for one revolution. As the distributor brushes of the sending station passes over segment number 1 it connects contact number 1 to the line. If this contact is open both line relays will remain on their space contact, but if the sending contact is closed, battery will be connected to the line relays and the current will cause them to operate to their marking contacts. As the distributor arm of the sending station passes over the segments numbered 2, 3, 4, and 5, the distributor arm of the receiving station will be passing over its corresponding segments. When the receiving distributor arm is on segment number 1 the first selecting magnet is then connected to the mark contact of the line relay. If the line relay has been operated to its mark contact by current in the line, battery is connected to this contact causing

the first selecting magnet to operate. If the line relay is operated to its space contact no battery is connected to the selecting magnet and hence it will remain unoperated. This procedure is continued for segments numbered 2, 3, 4, and 5. At the sending station

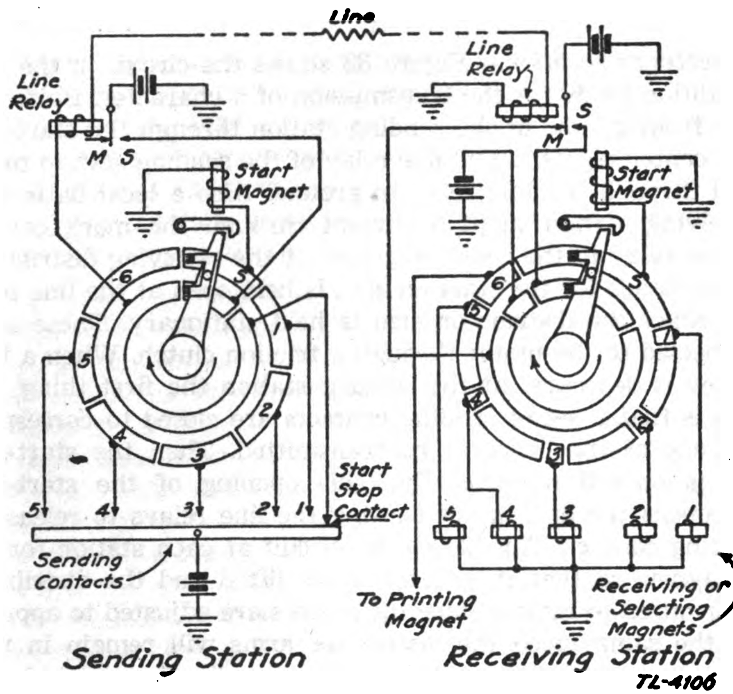

FIGURE 32.—Theory of start-stop system.

(through a mechanized arrangement) the start-stop contact, which has remained open during the transmission of the five impluses, closes as the distributor arm reaches the sixth segment. This causes both line relays to operate to mark, opening the circuit for the start magnet and, permitting the latches to catch the distributor arms and stop them. At the receiving station, as the distributor arm passes over the sixth segment, it connects battery to a printing magnet which prints the character set up by the selecting magnets. Both arms are stopped at the start segment and remain there until released by the opening of the start-stop contact

at the beginning of the next set of impulses representing a character.

It will be noted that the selecting segments of the receiving distributor are shorter than the segments of the sending distributor. This is to allow only the center of each impulse to be used, thus reducing the effects of distortion of signals.

46. Transmission in the modern machine.—In the modern machines the distributor is replaced by cams operating contacts in the proper sequence. The selection is also made through the use of cams so that the five selecting magnets and the printing magnet, shown in figure 32, have been replaced by a single selector magnet controlling the mechanized functions of the receiving mechanism.

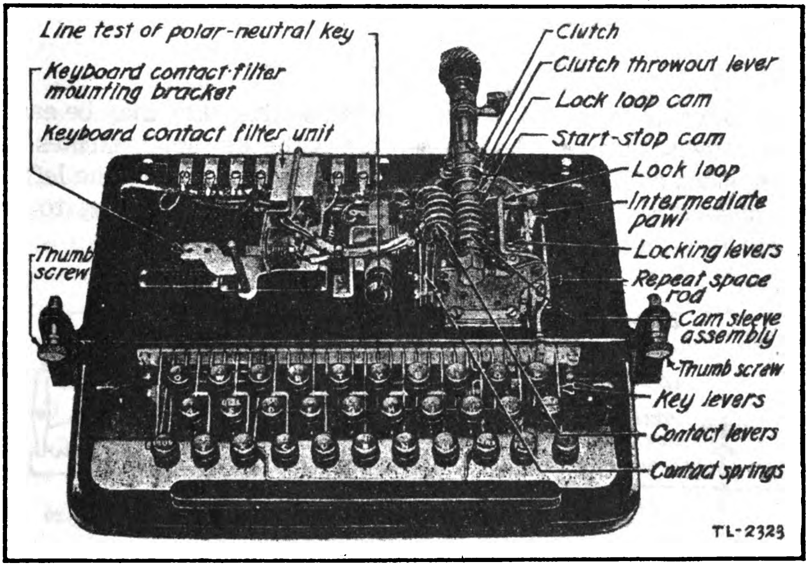

FIGURE 33.—Keyboard teletypewriter M–15.

a. Keyboard transmitter.—Figure 33 shows a view of the keyboard of the model 15 teletypewriter as used by the Army. Figures 34 and 35 show a more detailed view of the transmitting equipment.

(1) *Selector bars.*—Beneath the key levers are five selector bars and a universal bar extending across the width of the keyboard. The selector bars are provided with saw tooth notches (fig. 35) according to the requirements of the signaling code. These bars

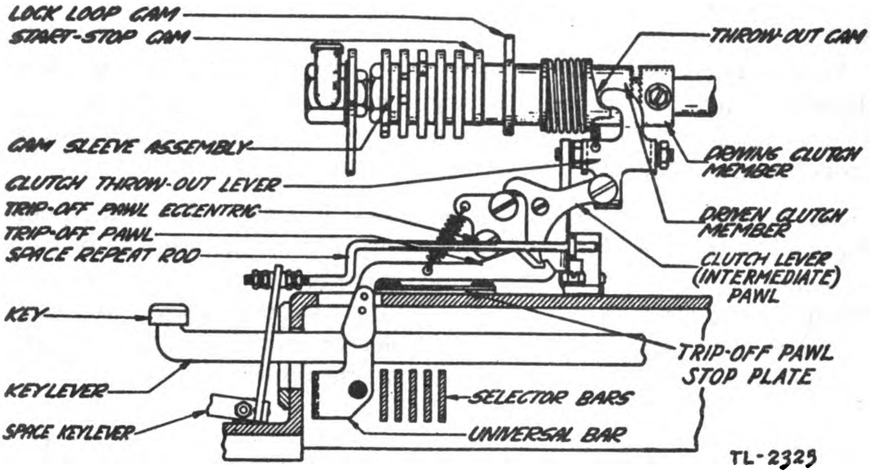

FIGURE 34.—Keyboard mechanism.

rest on rollers and are guided at each end so that they may be easily moved endwise. When a key is depressed the key lever strikes the slanting sides of these notches moving the bars either to the left or right, depending upon whether the impulses corresponding to the bars are to be marking or spacing.

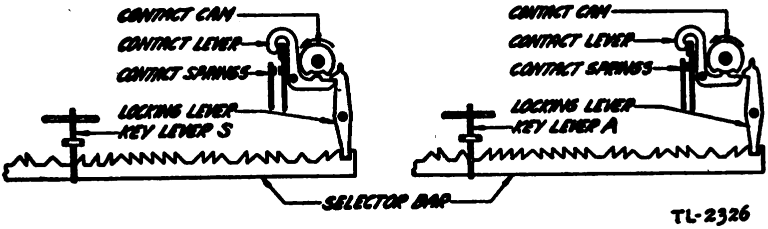

FIGURE 35.—Selector bar.

(2) *Universal bar.*—The universal bar (fig. 34), when operated, momentarily operates the clutch throw-out lever causing the driver clutch member to become engaged with the rotating driving clutch member. Thus, whenever a key or the space bar is depressed the selector bars and locking levers are set, and the universal bar is moved down, permitting the sending cams to start rotating.

(3) *Vertical locking levers.*—Each selector bar engages a vertical locking lever at its right hand extremity and positions it to

correspond with the signal impulses to be transmitted. Each locking lever controls the motion of a contact lever. If the upper end of the locking lever is positioned to the left, corresponding to a spacing impluse, it engages the contact lever and prevents it from rising into the indent of its cam as the cam rotates, thus holding the circuit open for that impulse. If the locking lever is positioned to the right, corresponding to a marking impulse, it does not interfere with the movement of the contact lever. Then, as the cam revolves, the contact lever rides on the cam surface and rises into an indent, thereby allowing its contact to close, sending out a marking impulse. As the cams rotate, the impulses, either marking or spacing, are transmitted in succession. It will be noted that there are five selector bars, locking levers, contact levers, and contact cams. In addition there is a start-stop cam with a contact lever riding on it. There is no locking lever associated with this contact lever. When the cam sleeve assembly is stationary the start-stop contact will be closed and all others open. When the sleeve is rotating the start-stop contact is opened and for a brief interval, representing the start impulse, there are no cam indentations in position to permit the closing of any contact. Then the first, second, third, fourth, fifth and start-stop cam indentations come into position for their contact levers to close their contacts unless restricted by locking levers. At the end of the revolution the clutch driven member is cammed out of mesh with the driving member and prevents the cams from rotating further until the next key is depressed.

(4) *Lock loop cam.*—The lock loop which is raised by the lock loop cam at the end of each revolution to allow the new combination to be set up is used while in its down position to prevent change in the selection set up (fig. 33). This is done by holding the locking levers in their set positions while the signals are being sent out. This arrangement also makes it impossible to depress another key until the signal for the previous character has been transmitted. All the pairs of contacts are connected in parallel and the group connected to the line for transmission.

b. Selection.—Figure 36 shows roughly the mechanical arrangement by which the received current impulses are translated to the code bars and figure 37 shows how these code bars determine the type character to be printed.

(1) *Starting of selection.*—When the receiving mechanism is ready to receive, the selector cam sleeve is held stationary by its

stop arm being caught on the stop lever which in turn cannot rotate because of the trip latch. The selector cam sleeve is connected to the drive shaft through friction clutches. Figure 36 shows only one selector lever, sword, "T" lever, and code bar though there are actually five of each. The projections of the selector cams on the cam sleeve are located at an angular displacement from each other as well as vertically displaced, so that each comes in contact with its selector lever as each of the five impulses are received. When the start impulse is received the armature is released and the armature extension moving the trip latch plunger causes the trip latch to release the stop lever which rotates to permit the stop arm to pass and the cam sleeve rotates.

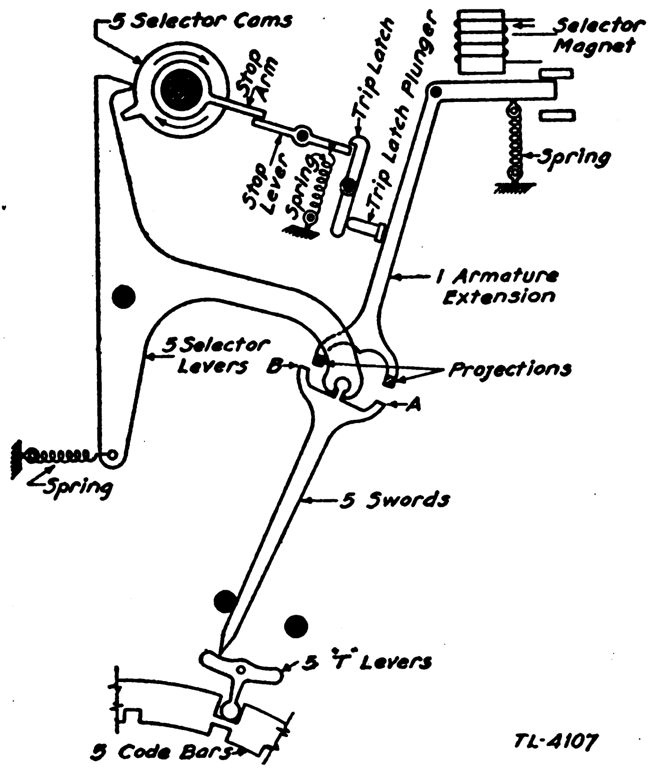

FIGURE 36.—Receiving mechanism of a single magnet teletypewriter.

(2) *Positioning of code bars.*—As the first selector cam comes in contact with its selective lever the first impulse will be received. If

the first impulse is marking, the armature extension will be moved to the right. At the end of the armature extension are two projections. When the selector lever is operated the sword is pulled back against one of the projections of the armature extension. If the extension has been moved to the right, the right side of the sword *A* will strike the right projection. The selector lever will pull the sword back a short distance further causing the sword to pivot around its right extension, moving its point to the left. Then as the selector lever rides off the selector cam projection the sword will be forced forward against the *T* lever rotating it and moving the code bar to the right. The next impulse will be received upon completion of the positioning of the sword. If the next impulse is spacing the armature extension will be to the left causing the second sword to be pointed to the right and moving the sword code bar through the action of its *T* lever to the left. This procedure is continued for each of the five swords and code bars. Following this the stop impulse will be received holding the armature extension to the right. This allows the trip latch to hold the stop lever so that as the stop arm completes its revolution it catches on the stop lever and holds the selector cam sleeve stationary until the next start impulse is received.

(3) *Printing of character.*—After the positioning of the code bars and before stopping, another cam on the sleeve caused the operation of the printing mechanism. Figure 37 shows the printing mech-

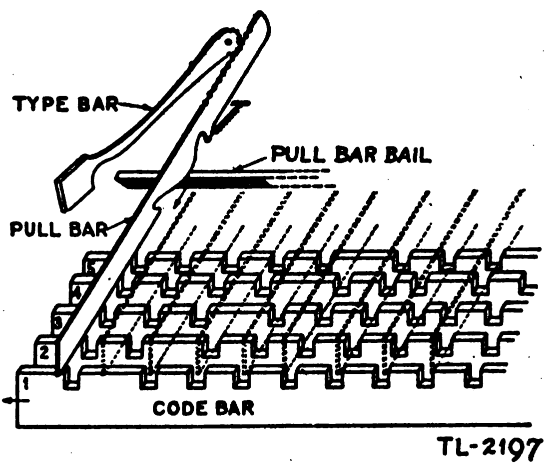

FIGURE 37.—Printing mechanism.

anism involved in the model 15 teletypewriter. As a result of the positioning of the code bars one set of notches in the code bars are lined up so that a pull bar may be permitted to drop into those notches. No other set of notches are so alined. Normally the pull bar bail holds all pull bars up off the code bars but in the operation of the printing mechanism the pull bar bail moves forward and this allows all pull bars to be lowered to rest on the code bars. One pull bar will drop into the set of notches properly alined. The pull bar bail will continue to move forward and will catch in the notch of this one pull bar pulling it forward also. As the pull bar moves forward the type bar is raised and the type strikes the paper, printing the character transmitted. At this point the pull bar bail returns to its normal position lifting all pull bars from the code bars so as to permit the repositioning of the code bars.

(4) *Selection of functions.*—The selection of the special functions of carriage return, line feed, etc., is performed in the same manner as for characters but for these particular code combinations there will be no alinement of notches to permit a pull bar to be operated and no character will be printed. However, the positioning of the code bars does cause the operation of other levers to produce the functions desired.

c. Orientation.—Due to the wave shape of the signals involved it is important that the small portion of the signal that is to be employed in the selection phase of reception should be from the section of the signal with the maximum strength. Thus, in figure 38, section B is obviously the one desired. It can be seen from this figure that in order to properly operate the selector mechanism, it is necessary to place the starting point of the selector cam sleeve in the most favorable position. This is accomplished by means

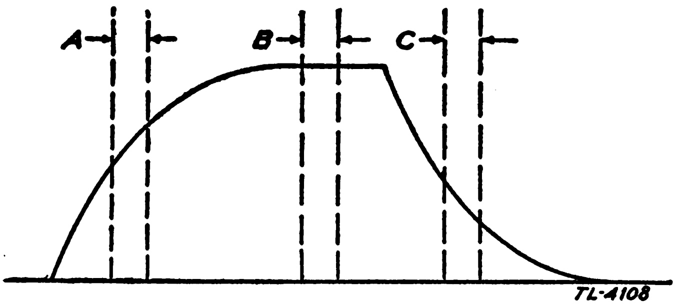

FIGURE 38.—Selection periods.

of the range finding mechanism, which is used to orient or take a range. This is reached through a hinged door in the left side of the cover to the teletypewriter.

(1) *Range finder mechanism.*—Mounted on the stop lever plate (which is part of the range finder mechanism) are the stop lever and the trip latch which may be rotated, thereby varying the relation between the start of the selector cam sleeve and the time the selector cam operates the selector levers. A graduated scale indicates the setting of the stop mechanism (range), and the thumb screw holds it in place after having been set.

(2) *Range measurement.*—The range is determined while receiving "RYRY" on the printer, by first moving the range finder index arm in one direction until errors appear and then back slowly until the errors disappear, and noting this latter position on the scale. In a similar manner, the other limit of the range is located by moving the index arm toward the opposite end of the scale. These limits represent the "range" of the machine, and should be at least seventy points apart, with the low point at twenty (20) or below (preferably between 15 and 20). This is so that allowable differences in adjustments will not materially affect the working range of the loop. The loop working range is between the highest of the low points and the lowest of the high points of all machines connected on the loop. The proper setting of each machine is the midpoint of these two limits. This applies to machines permanently connected in a loop. When connected to a switchboard the range should be measured while receiving from the switchboard and the midpoint of this range used as the final setting of the range finder mechanism.

d. Summary.—The types of mechanism employed vary considerably but are usually almost entirely mechanical. In general, the complete operation of teletypewriters may be divided into three parts:

(1) *Transmission.*—At the sending station, each operation of a key on the keyboard actuates a sending distributor to transmit the required signals, which consist of the start impulse, the necessary selecting pulses, and stop pulse.

(2) *Reception and selection.*—The signals transmitted are usually received by a line relay at each receiving instrument. This line relay controls the receiving mechanism which sorts out the pulses and selects the character to be printed.

(3) *Printing.*—After the selection has been made, the printing mechanism is actuated. The printing mechanism then prints the character, or performs the required function, and returns to normal position to await the next operation.

47. The M–15 teletypewriter.—The principles of operation just discussed apply to the model 15, 14, 26, and 19 teletypewriters. These machines differ only in the mechanical arrangement of the parts. The machine adopted as standard in the army is the M–15. In general appearance the M–15 resembles an ordinary commercial typewriter with a few additional keys or switches, and is known as a type bar page teletypewriter. A power switch located in the front right corner and projecting through a slot in the printer cover must be placed in the "ON" position before any message can be sent or received.

a. Keyboard.—The keyboard is similar to the keyboard of a standard commercial typewriter with a few exceptions as follows:

(1) Only capital letters and figures are used. There are no intermediate or small letters.

(2) To shift to the figures position, the key marked FIGS must be depressed.

(3) To unshift or return to letters position, the key marked LTRS must be depressed. Some machines are also arranged to unshift upon depression of the space bar.

(4) Operation of the key marked CAR RET causes the type carriage to be returned to the left hand margin of the paper.

(5) Operation of the key marked LINE FEED causes the paper to be advanced to the next line.

(6) On machines equipped with the automatic space repeat feature, the carriage continues to space as long as the space bar is held depressed.

(7) On the upper case of the S key, the word BELL appears. This is a signal bell and is used to summon the attendant at a distant station. First the FIGS key must be depressed. Then with the mechanism in figures position, the signal bell will ring once for each operation of the S key. Where there are several stations on a single line, a code is usually agreed upon so that the sender may summon the attendant at any particular station.

b. Motor stop.—On the upper case of the *H* key, the word STOP appears. This means MOTOR STOP. On some machines, upper case *M* is used for MOTOR STOP. If the FIGS key is depressed and then

the *H* key, the printer motors of all the machines on the circuit will stop. To restart the motors, the SEND-REC-BREAK key must be depressed momentarily to the BREAK position. As soon as the SEND-REC-BREAK key is restored to the REC or SEND position, the printer motors of all machines on the circuit will start.

c. Test key.—Just below the sloping portion of the cover, there is a small hinged door which may be raised to provide easy access to the line-test key on the keyboard. With this key normal or *in*, the teletypewriter is connected to the line and anything written upon it will be reproduced on other machines on the line. With this key pulled *out*, an artificial circuit is provided for testing the machine locally without disturbing other machines on the line. This key is also sometimes arranged to permit the machine to be operated on either polar or neutral circuits. With the key *in*, it is connected for polar operation. With the key *out*, it is connected for neutral operation.

d. Platen.—In this machine the paper remains stationary while typing and the type basket moves across the paper from left to right. This is opposite from the normal typewriter conditions. When the machine is changed from LTRS position to the FIGS position, the platen with the paper is raised as in some types of typewriters. There is also a margin bell on the right margin as in the case ot typewriters to give a warning when the right margin is approached. The margins, however, are not adjustable as in the typewriters.

e. Send-Receive-Break key.—The SEND-RECEIVE-BREAK key actually consists of two levers, one projecting out from the cover, the other extending to the edge of the cover only. When the longer lever is in the SEND position the machine will be connected for reception as well as transmission but if this lever is in the RECEIVE position the keyboard contacts are shorted and reception only is possible. This lever cannot be operated to the BREAK position unless the shorter locking lever is also moved to that position. When this is done the circuit is opened, causing all machines connected in this circuit to "run open." This procedure is often used to break into the transmission from a distant station. The send-receive switch on all other machines in the circuit will be thrown to the receive position automatically when a break is transmitted. It must be manually restored to SEND in order to transmit.

f. Blank key.—One key on the keyboard is blank and has no character on it. In some machines operation of this key once causes the send-receive switch to be operated to the receive position. This will

lock out the keyboard of all machines so equipped. However, some machines are so arranged that this blank key must be operated twice in order to lock out the keyboard. This arrangement is often required since in some instances motor-stop operates from the combination FIGS-BLANK-STOP and a single operation of the blank key must not kill the keyboard.

48. The M–14 teletypewriter.—This teletypewriter is known as a type bar tape teletypewriter and is similar to the M–15 except that it types upon a tape. The arrangement of the equipment is such that the tape passes just above the keyboard so that it is readily visible to the operator. This machine is found only at special installations in the army.

49. The M–26 teletypewriter.—The M–26 teletypewriter differs from the M–15 as follows:

a. There is no line test key built into the machine.

b. In this machine, the platen and paper move from right to left when typing as in the case of the regular typewriter.

c. The platen does not change position when shifting from LTRS to FIGS. This is taken care of in the typing mechanism.

d. The type instead of being arranged in the form of a type basket as in a typewriter, is mounted as pellets on a type wheel. This wheel is revolved until the correct type pellet is in position and then a printing hammer strikes the pellet to type the character.

e. The machine is smaller and makes less noise than the M–15.

f. It is not as sturdy as the M–15 and for this reason is not the standard type accepted by the army.

g. Where the M–15 is also adaptable to sprocket feed whereby many copies of forms may be typed, the M–26 cannot be so adapted, though it is capable of making carbon copies of messages.

h. The M–26 cannot use a tabular mechanism as can the M–15.

i. The M–26 does have the advantage of costing only about half that of the M–15.

j. The selector mechanism on the M–26 is located on the top of the typing mechanism and cannot be reached without taking off the cover of the machine.

k. The power switch is located on the table instead of on the machine. This is in reality three switches, each a single-pole double-throw switch. They are fastened together in such a way that a three-pole double-throw switch is formed. When this switch is in

the OFF position, the a-c power is turned off and the line has a short placed on it instead of the printer circuit.

l. The SEND-REC-BREAK switch does not appear on the M–26 and it is always in the SEND position where it will both send and receive. A BREAK switch in the form of a button is located on the base to the left of the keyboard. By pressing this button, the circuit is opened and the break signal transmitted.

m. Both the M–15 and the M–26 may be set to double space if desired and both may be equipped with motor-stop mechanism.

n. The M–26 does not have a blank key.

50. The M–19 teletypewriter.—The M–19 teletypewriter actually consists of an M–15 teletypewriter with the addition of three units, a tape perforating mechanism, a character counter and a transmitter distributor. In addition, a reperforator may also be installed as an additional unit if the traffic warrants. The tape perforating mechanism, character counter, and the keyboard and base of the teletypewriter are made up in one unit and termed the teletype M–15 perforator transmitter.

a. Keyboard control lever.—A manually operated, three-position keyboard control operating lever, mounted on the right side of the unit, permits the operator to select any one of the following methods of operation:

(1) Operating lever in upper or keyboard position.—Direct keyboard transmission to the line with a printed record being produced at the transmitting point. The maximum speed of the keyboard is limited to the predetermined speed of the set.

(2) Operating lever in middle or keyboard and tape position.—Simultaneous direct keyboard transmission to the line and perforation of tape with a printed record being produced at the transmitting point. The maximum speed of the keyboard is limited to the predetermined speed of the set.

(3) Operating lever in lower or tape position.—Perforation of tape only with the associated printer either receiving messages from a distant station, or monitoring the message perforated in the tape as it is being transmitted to the line. The indicator on the character counter moves each time a character key is depressed. The counter is provided with a signal lamp to indicate when the end of a line is being approached. The maximum speed of the keyboard in this case is not limited to the predetermined speed of the set and the operator may, therefore, perforate tape at speeds much greater

than the speed at which a tape transmitter would send to the line.

(4) Operating lever in middle or keyboard and tape position and line test key in test position.—It is also possible to perforate and print a home record without transmitting directly to the line when the test key (located near the center of the keyboard) is in the test position. This method is helpful in preparing perforated tape for use in connection with printer forms. The maximum speed of the keyboard is limited to the predetermined speed of the set.

51. The keyboard tape perforator.—The keyboard tape perforator is a mechanism that perforates a tape as shown in figure 31. This is a small machine with keyboard and tape perforator but without the associated teletypewriter. Thus, if all teletypewriters are busy, tape may still be perforated and later sent out over the transmitter distributor. A hole is punched for a marking pulse and the paper left intact for the spacing pulse. The line of smaller holes down the center of the tape is used to feed the tape through the the machine. This unit, which is the same as the keyboard and perforator position of the M–19, is not operated by a motor but is entirely mechanical with an electromagnet operating the punches as set up by the key levers.

a. Back space lever.—A back space lever is provided for moving the tape backwards for the correction of errors. When this lever is moved from left to right, the tape is moved back one position and then the letters key may be depressed, causing five holes to be perforated over the error. This combination may be passed through the tape transmitting device without printing any character or letter on the receiving printer. However, if a character in the upper case is removed it will be necessary to strike the shift key again, because the "letters" combination will unshift the receiving printer.

52. The transmitter-distributor.—This machine is a motor driven, combination tape transmitter and distributor. Its purpose is to translate the code combination, perforated in the tape, into electrical impulses and transmit these impulses to the receiving station. There are two types of distributors of this class—one operates on the five unit code and the other on the six unit code. The two, however, are almost identical, the only difference being that the six unit type has an additional contact, lever and commutator segment to take care of the additional sixth unit. The tape transmitter, utilizing the perforated tape, sets up the code combinations to be transmitted. The commutator distributor sends the code combina-

tion out over the line as marking and spacing impulses, in proper sequence and at a predetermined speed. The two units are driven together by either a governor-controlled motor or a synchronous motor operating at a constant speed.

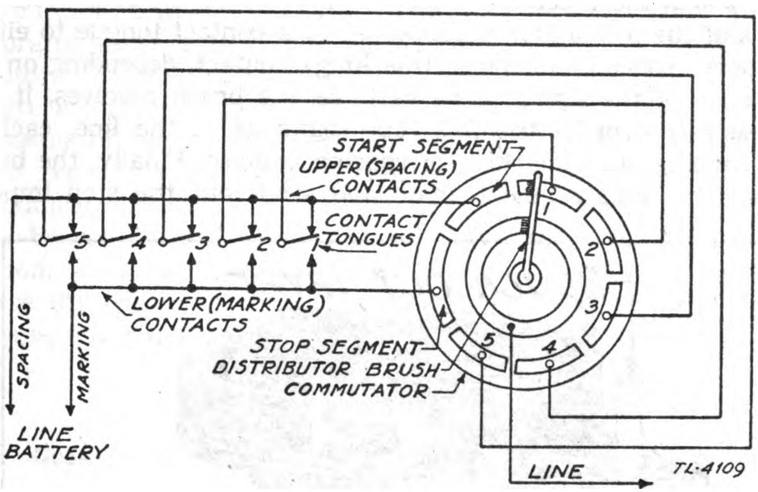

FIGURE 39.—Simplified circuit of transmitter-distributor.

a. The commutator.—The commutator is made up of two concentric conducting segment rings attached to an insulating disc. The outer commutator ring is composed of seven segments. Five of these segments correspond to the five intervals of the code. Immediately preceding the No. 1 segment is the "start" segment, while the segment following No. 5 is the "stop" segment. (See fig. 39.) When the brush passes over the start segment, a spacing impulse is always transmitted, whereas a marking impulse results when it passes over the stop segment. These two invariable impulses cause the receiving mechanism to operate in unison with the distributor brush arm. The inner commutator ring is a solid ring which is connected to the line, and as the distributor brush arm revolves, it connects the segments of the outer ring successively to the line.

b. Transmission.—As indicated by the wiring diagram (fig. 39), the five tongues on the tape transmitter move between the upper and lower contacts, called the "spacing" and the "marking" contacts respectively. The perforations in the tape determine which contact tongues will be on spacing and which on the marking con-

tacts. When the distributor brush is on the stop segment, no signals are transmitted and marking current is sent to the line. At such a time, the selector at the receiving terminal will be held at rest. To transmit a combination of impulses, the distributor brush revolves in the direction indicated. It will first pass over the start segment, sending a spacing impulse over the line. This impulse starts the receiving mechanism. Each of the five code segments of the distributor is connected by a contact tongue to either an upper (spacing) or lower (marking) contact, depending on the character of the signal to be sent. As the brush revolves, it will successively connect the five code segments to the line, each in turn sending out a marking or spacing impulse. Finally, the brush reaches the stop segment again and sends out the stop impulse

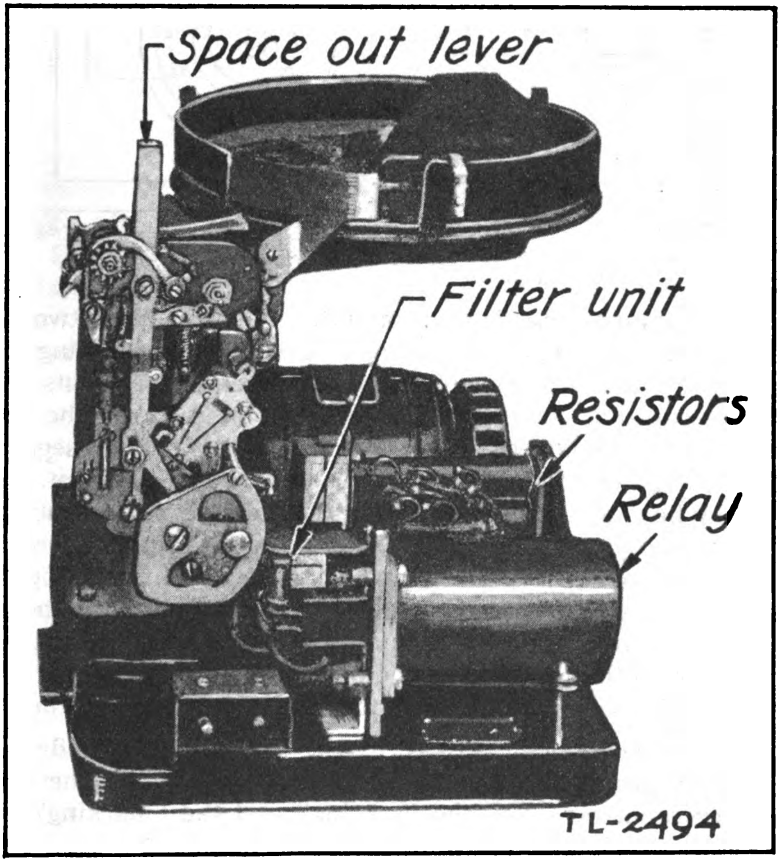

FIGURE 40.—Reperforator.

which stops the receiving mechanism. This start-stop system keeps the receiver in synchronism with the distributor.

53. The reperforator.—If a message is to be relayed through a station, there are three ways it might be done; it might be received on a printer and retransmitted by an operator on another M–15 machine, or it might be received on an M–15 and then with a perforator make a tape and run through a tape transmitter-distributor. But both of these methods require too much time and require an attendant to perforate the tape. The third method is by means of the reperforator (fig. 40). This is a small machine which receives the electrical impulses and, converting them into mechanical operations, perforates a tape which may then, at any time, be run through a tape transmitter-distributor for retransmission. This requires very little attention from the operator. Where the traffic warrants, the reperforator will be used. As an average, one will be used with every two M–19 teletypewriters.

54. Questions for self-examination.—

1. The teletypewriter consists of what two major mechanical parts?
2. How does the teletypewriter code differ from the Morse code?
3. What special functions must be provided for in the code besides the letters of the alphabet and numerals?
4. What system is used to synchronize teletypewriters?
5. Why is it necessary to use such a system instead of synchronous motors on the machines?
6. What is the nature of the start and stop impulses?
7. In the modern machine how many magnets control the selection and printing of a character?
8. How many distributors are employed in a complete M–15 printer?
9. What is the purpose of the vertical locking levers?
10. What is the purpose of the lock loop?

11. What is the purpose of the line test key?

12. What is meant by orientation?

13. How is the range determined on a teletypewriter?

14. What is meant by the word STOP appearing on the H key?

15. What is the function of the SEND-RECEIVE-BREAK key?

16. How does the M–14 differ from the M–15?

17. How does the M–26 differ from the M–15?

18. Of what is the M–19 composed?

19. What is the effect of the keyboard control lever upon the operation of the M–19 machine?

20. Explain the use of the keyboard tape perforator.

21. How does the transmitter-distributor convert code perforations to electrical impulses?

22. What is the purpose of the reperforator?

SECTION VII

TELETYPEWRITER CIRCUITS

	Paragraph
General facilities employed	55
Basic teletypewriter circuits	56
Wiring of teletypewriter	57
Motor circuits	58
Power supplies	59
Questions for self-examination	60

55. General facilities employed.—Various types of circuits are used in connection with teletypewriter operation. Open wire or cable may be used and the means by which telegraph channels are secured will, except in rare cases, be by means of superposition. That is, the telegraph channel will be obtained from a given wire or wires in addition to those wires being used for telephone service. This superposition may be by simplex of a physical circuit (SX), simplex of a phantom circuit (SXP), physical or side circuits composited (CX), or a phantom circuit composited (CXP). These methods are represented in figure 41 and are covered in more detail in section II.

56. Basic teletypewriter circuits.—Basically a teletypewriter consists of two fundamental electrical units. The receiver mechanism electrically consists of the selector magnet with its leads brought out to terminals and may be compared to the common sounder as employed in Morse telegraphy. The transmitting mechanism electrically consists of the keyboard or transmitting contacts with leads brought out to terminals and may be compared with a telegraph key which has the circuit normally closed but is opened upon pressing the key, such as an open-circuit type of key using the back contact instead of the front. This "key" and "sounder" of the teletypewriter may be connected into any circuit, neutral, duplex, polar, or otherwise, in which such a Morse key and sounder would be used. Their use in the more complex circuits of course call for the use of relays and the requirement here is that the relay be capable of

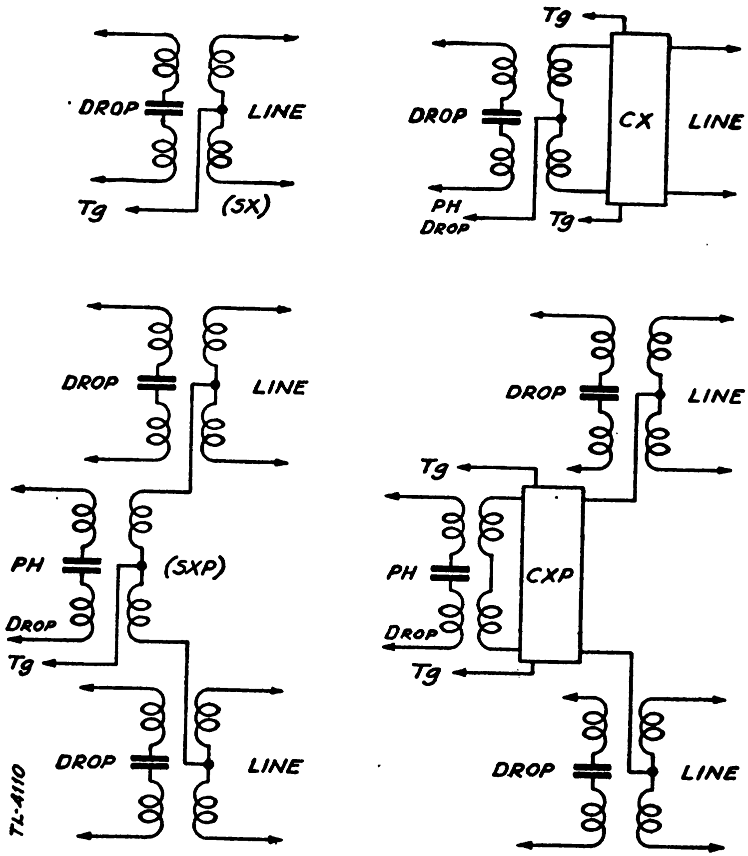

FIGURE 41.—Methods of obtaining telegraph channels.

accurate response to the high speed telegraph signals to be transmitted. Likewise the circuit constants should offer a minimum of distortion to the signals being transmitted.

a. Direct neutral connection.—The simplest connection of teletypewriters is as shown in figure 42. Here the selector magnet is connected with the transmitting contacts in series with the line. If ground return is to be employed one of the line connections shown in figure 42 would be connected to ground while the other would go to the telegraph line circuit. Two or more machines may be connected in a circuit by connecting them in series. Line current is supplied by a direct current power source as discussed in paragraph 59.

b. Use of single-wound relay.—Though the teletypewriter will work satisfactorily in the circuit as shown in figure 42, it may be worked satisfactorily over greater distances and over poorer line facilities by employing the use of a relay. If a single-wound, neu-

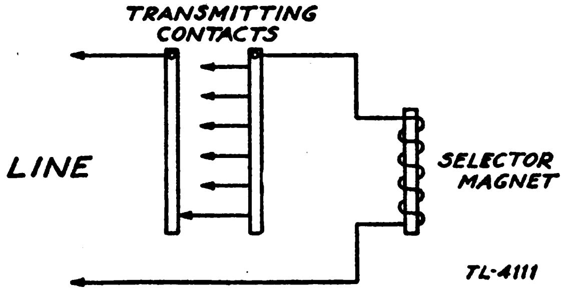

FIGURE 42.—Simple neutral connection.

tral type relay is to be used the circuit will be that of figure 43. In this circuit the selector magnet is removed from the line circuit and connected in a local circuit in series with a direct current power source and the mark contact of the relay. The relay winding is connected in series with the transmitting contacts in the line. With the

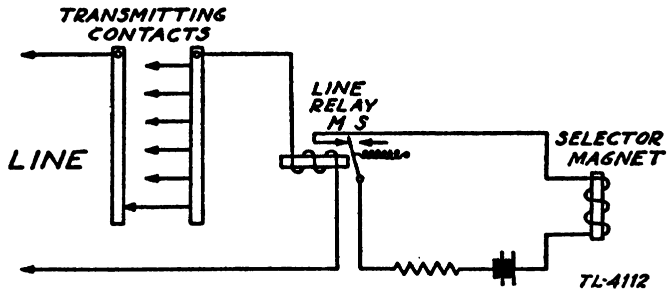

FIGURE 43.—Use of single-wound relay.

line circuit closed, the line relay will be operated to its mark contact. This closes the local circuit and operates the selector magnet.

c. Use of double-wound relay.—Figure 44 shows the circuit employed when the double-wound type relay is used as a line relay. This circuit differs from that of the single-wound relay circuit only in the addition of the bias winding circuit consisting of the bias winding, a current limiting resistance and a source of direct current.

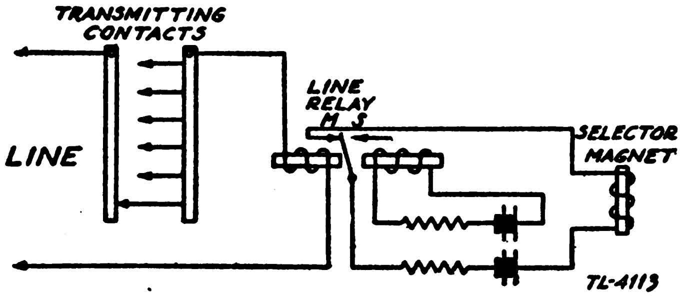

FIGURE 44.—Use of double-wound relay.

As shown in figure 44 separate power sources are required for the local circuit, bias circuit and the line circuit. A single power source

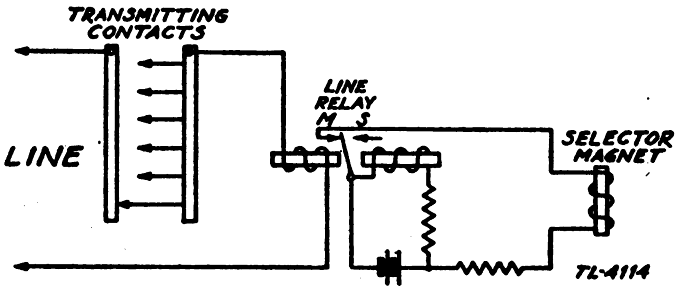

FIGURE 45.—Common power supply.

may be used as shown in figure 45 for bias and local circuits. By connecting the line circuit through this same power source, line current may also be supplied without additional power source providing the available power source has sufficient capacity.

57. Wiring of teletypewriter.—The wiring for the individual components of the teletypwriter is brought out to terminal strips in the machine so that they may be connected in whatever type of circuit that is to be used. The wiring differs in the different types of teletypewriters and reference should be made to the technical instructions furnished with the individual machines for details of wiring. The break key which is also brought out to a terminal strip is normally wired in series with the transmitting contacts.

58. Motor circuits.—The motors employed in teletypewriters are of two general classifications: (1) synchronous with speed constant, and alternating current supply required; (2) the governed type

with speed adjustable and either alternating or direct current supply necessary depending upon the individual motor.

a. Synchronous motor.—Figure 46a shows the circuit involved with the use of a synchronous motor. The centrifugal switch is closed at the start, connecting the start winding into the circuit, but is opened when the motor nears its proper speed. If the motor stop control is not desired the motor stop control contacts are shorted out. A capacitor is placed across this switch and motor control

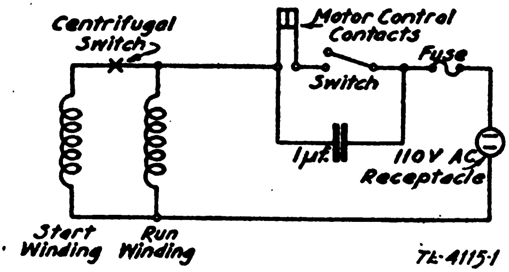

FIGURE 46a.—Synchronous motor.

contacts to reduce arcing when the switch or contacts are opened. Teletypewriters equipped with synchronous motors may be operated only where there is an alternating current supply having a voltage and frequency corresponding to the rating of the motor used.

b. Shunt d-c motor.—Where only direct current is available for running the motor a shunt direct-current motor may be used as shown in figure 46b. This motor is of the governed type. The governor contacts are controlled by the speed of the motor. At the

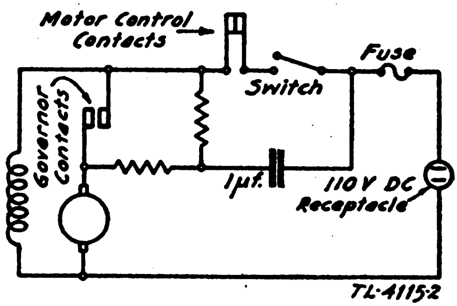

FIGURE 46b.—D-c shunt motor.

start the contacts are closed but as the motor speed rises above the proper speed they open to insert a resistance in series with the

armature circuit, decreasing the current through the armature and thus decreasing the motor speed.

c. Speed adjustment.—There are several methods of adjusting the speed of the governed motors of teletypewriters. The fan wheel of the motor has black and white lines marked around its rim. A tuning fork is provided which has small vanes fastened to the ends of the prongs and pointing toward each other. As the fork is vibrated the vanes move back and forth opening and closing the gap between them. The motor speed is adjusted so that, when the rim of the fan wheel on the motor is observed through the slit between the vibrating vanes on the tuning fork, the black and white lines appear to be stationary. However it is possible to adjust the speed of the motor without a tuning fork. With a sixty word per minute printer it requires 0.163 second for the transmission of each character. The margin bell on the teletypewriter should ring when 66 characters have been printed from the left margin. If the carriage is returned to the left margin and the space bar is held down for continuous spacing the margin bell should ring at slightly more than eleven seconds. When calculating the time it should be remembered that there will be a mechanical time lag of approximately two spaces between the time when the bell is tripped and when it rings. The speed of the motor may be adjusted until this time is correct.

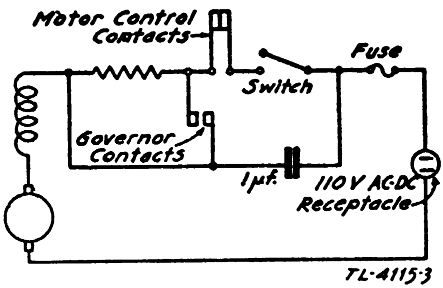

FIGURE 46c.—Series a-c d-c motor.

d. Series a-c d-c motor.—Figure 46c shows the circuit for a series motor. Here the armature and field are in series and the governor again inserts resistance in series with the armature (and field) to reduce the speed and cuts it out to increase the speed.

59. Power supplies.—If an external power source of direct current is available and a direct-current motor is used, this direct-current power source may be used to supply the current for the local cir-

cuits as well as line current. However, if alternating current is the only power available, then some means must be used to convert this alternating current into direct current to supply the local and line currents. A motor-generator set may be used to supply the necessary current, or a rectifier may be used. Figure 47 shows the circuit of the more common type copper-oxide rectifier. The sec-

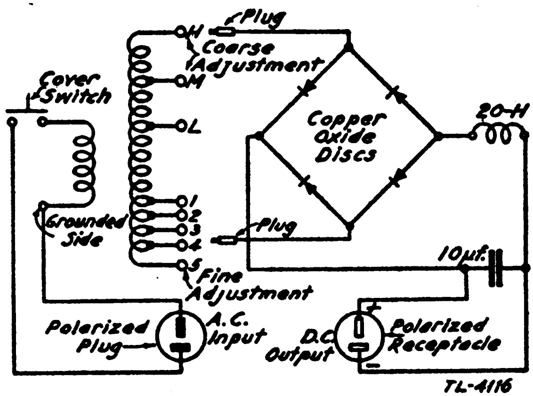

FIGURE 47.—Rectifier circuit.

ondary of the transformer has taps brought out so that the output voltage of the rectifier may be adjusted to its proper value. The copper-oxide rectifier operates on the principle that if two dissimilar metals are in contact, current can flow between them more easily in one direction than in the other. Copper and copper oxide are used in the same manner as two dissimilar metals, to form the elements of the copper-oxide rectifier. This combination offers low resistance to current flowing from the copper oxide to the copper, but offers a very high resistance to the flow of current from the copper to the copper oxide. Thus it becomes of value for the rectification of alternating currents. In figure 47 the triangle represents the copper oxide and the straight line represents the copper, thus indicating the direction of the current flow through the circuit.

The output of the rectifier is passed through a filter to smooth out any ripples. While the motor of the teletypewriter might operate on either direct or alternating current, depending upon the design of the motor, the local operating circuits and the line circuits require direct current. This may even be supplied from batteries. Line current should normally be adjusted to 60 milliamperes. The current may vary materially from this value and still maintain

satisfactory operation. The permissible current variation depends upon the constants of the circuit. The current required in the selector magnet, bias circuit, or other circuits that might be connected will vary with the type of equipment used. The value of these currents may be obtained from the technical data furnished with each teletypewriter.

60. Questions for self-examination.—

1. What type of facilities may be employed for teletypewriter circuits?

2. What pieces of Morse equipment might be used to represent a teletypewriter?

3. What is the simplest circuit for connecting a teletypewriter in a line?

4. How may three machines be connected in a circuit?

5. Draw the circuit for a teletypewriter using a double winding line relay with common battery supply for local and line currents.

6. How may speed of a governed teletypewriter motor be adjusted?

SECTION VIII

TELEGRAPH REPEATERS

	Paragraph
Principle of repeaters	61
Duplex repeaters	62
Single-line repeaters	63
Regenerative repeaters	64
Questions for self-examination	65

61. Principle of repeaters.—Previous sections have shown the satisfactory operation of a properly adjusted relay depends upon the reception of the proper amount of current through its coils and upon the amount of distortion the signal picked up in transmission. These factors depend, in turn, upon the length of the line and its constants. Where a line is so long that the line constants prevent satisfactory operation, it may be cut in the middle and made into two independent circuits, each of which is short enough to operate. Call these independent circuits *A* and *B*. Now an operator located at the midpoint could hear signals made by the operator at the distant end of *A* and could transmit them to the operator at the distant end of *B*. He would be repeating the message, or as we usually speak of it, relaying the message. The repeater is simply an electro-mechanical device to take the place of an operator at the midpoint. It repeats the signals received from *A* to *B*, simultaneously with the reception.

62. Duplex repeaters.—Since duplex repeaters are more easily understood than the single-line repeater, the polar direct-point repeater will be explained first.

In figure 48 are two independent double-current duplex circuits. Designate the two end stations as East and West, and the common station from which the lines run to East and West as Center. Disconnect Center's left hand line from the key and connect it to the armature of Center's right hand relay; connect positive and negative battery to the space and mark contacts, respectively, at Center's right hand relay.

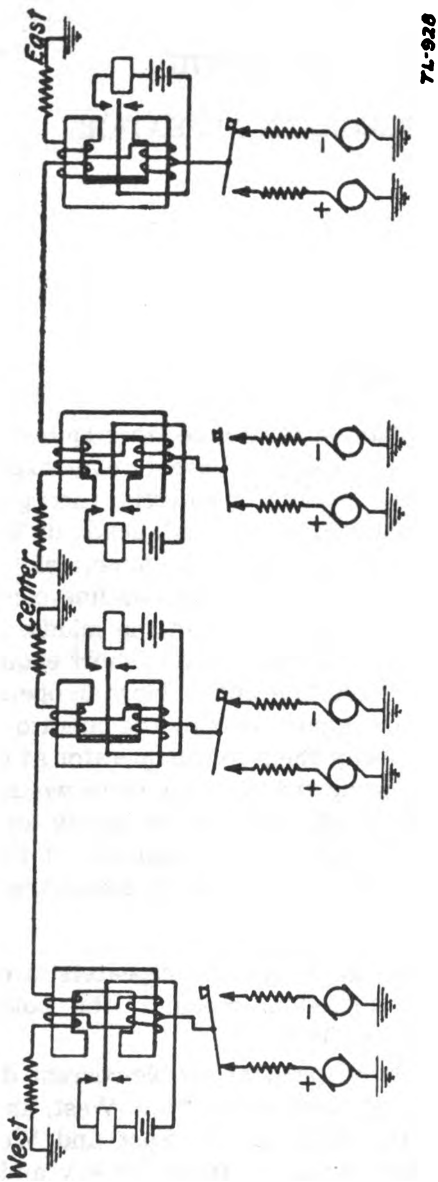

FIGURE 48.—Two independent duplex systems with common location of one terminal.

Then perform a similar operation with the right hand relay line and contacts at the left hand relay. The result is shown in figure 49; it is a polar direct-point repeater.

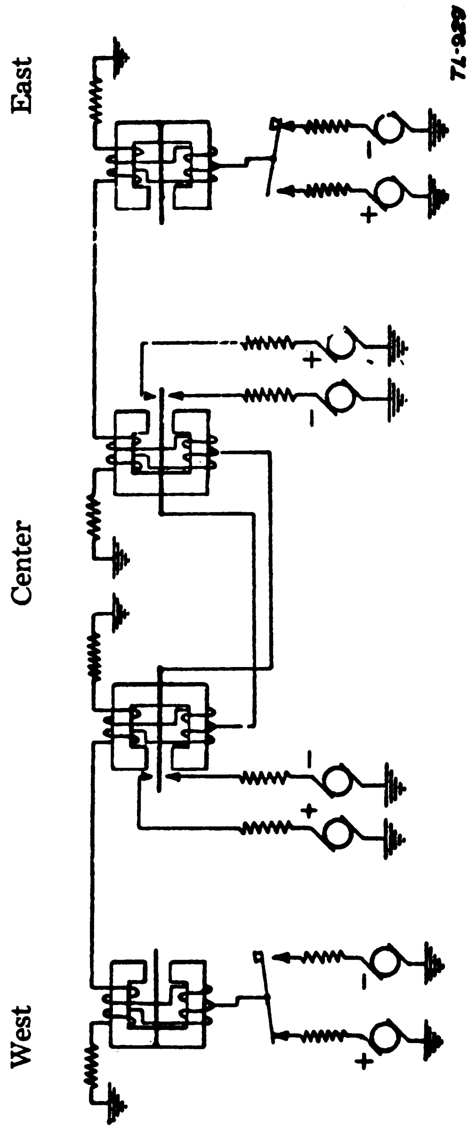

FIGURE 49.—Polar direct-point repeater.

When West depresses his key, Center's left hand relay pulls its armature to the mark contact. This connects negative battery to the right hand line and causes East's relay to pull up to the mark position. The signal made by West has been repeated to East. The action in all cases is exactly like that explained under differential duplex.

63. Single-line repeaters.—*a. Closed-circuit system.*—In a neutral system where the receiving operator must be able to break in on the transmitting operator, a device that will repeat the signal in both directions is not so simple as the polar direct point repeater. The theory of this device can be understood best by studying its operating features step by step. First let us suppose that two intermediate relays are connected into a simple circuit as shown in figure 50a, with the winding of one relay in series with the contacts of the other and vice versa. It is evident from a study of figure 50a that this circuit does not meet the requirements of a repeater. It is a step in the right direction, but opening either key will result in opening both circuits at the intermediate station and the closing of either or both keys cannot restore the contacts of the R_W and R_E relays. In order that this device shall function it is necessary to add to each relay an additional coil so wired that its own armature will be closed while the armature of the other relay is released, regardless of circuit condition of its own main windings. These coils

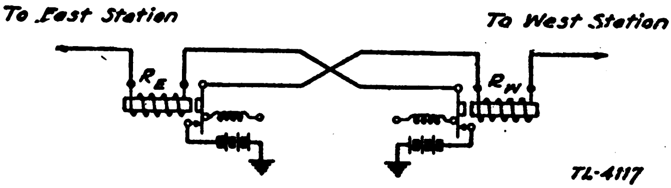

Figure 50a.—Telegraph repeater line circuit.

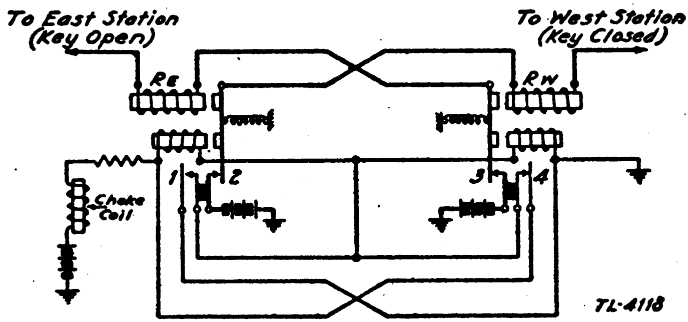

Figure 50b.—Single Morse repeater circuit.

are called holding coils and figure 50b shows the holding coils added to the circuit of 50a. The battery for the holding coils is a local one and is not connected to the line in any way. It is repre-

sented by light lines to distinguish it more clearly from the main line telegraph wires. The two holding coils are in series and each line relay is equipped with an additional set of contacts that shunt the holding coil of the other relay when closed. The resistor in series with the local battery is to limit the current flow when the holding coils are short-circuited, and the induction coil quickens the action of either holding coil when the shunt is removed. The operation is now as follows: when both East and West keys are closed, the main line coil holds the armatures of both relays R_W and R_E to the mark position and both holding coils are shunted out through the contacts *1* and *4*. Now suppose the East operator opens his key. The main line relay of R_E will be de-energized and the armature will be moved to the space position by a spring, breaking contact *1* and *2* and repeating the space signal to the West operator. When contact *1* is broken, the shunt on the holding coil of R_W is removed at the same instant the main line coil is de-energized and the energized holding coil holds the armature to the closed position. The armature of R_W is held closed by the holding coil while the East operator is spacing. When the East operator closes his key, the main line circuit through R_E will be completed and the main line coil will pull the armature back to the marking position, closing the contacts of R_E which close the main line circuit of the West station and shunt the holding coil of R_W so that both armatures are again under the control of the operator's keys. If the West operator desires to break while the East operator is sending, he merely opens his key. As the East operator continues to send, the next signal that closes his circuit, and shunts the holding coil of the R_E relay, will render this holding coil inoperative and permit the R_W armature to move to the space position, breaking the East operator.

b. Open-circuit system.—The repeater described above cannot be used on the open-circuit telegraph system. However, an open-circuit repeater is a very simple device and can be constructed quickly using two neutral relays with front and back contacts and a battery. A circuit diagram of an open-circuit telegraph repeater is shown in figure 51. Like the closed-circuit type in figure 50b the winding of one relay is in series with the contacts of the other. On the front contacts battery of sufficient capacity to operate the system is connected. The operation of the repeater is as follows: when the circuit is idle with both keys open (back contacts closed) the armatures of R_E and R_W are held on the back contacts by the springs, closing the line circuit through the relay windings to ground. No

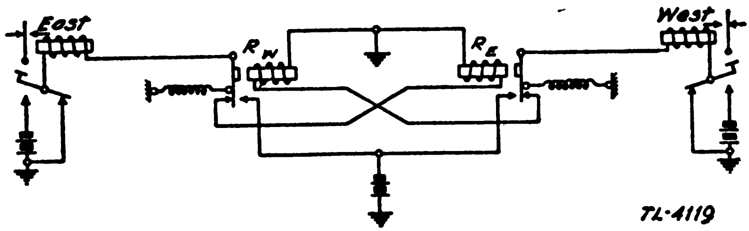

FIGURE 51.—Open-circuit repeater.

battery is in this circuit, therefore, the relay windings are de-energized. Now suppose the East operator closes his key. The relay R_E will now receive current from the East battery and become energized, closing its front contacts. Since battery is connected to the front contact of the R_E relay, current will flow in the West circuit and the signal will be repeated to the West operator. Should the West operator desire to break, he merely closes his key. As East continues to send, the next spacing signal will give the West operator control of the R_W relay.

64. Regenerative repeater.—The high speed operation commonly used with teletypewriters is possible only if the received signals are free from any large amount of distortion. Since telegraph signals are invariably distorted to some extent in the process of transmission and since the ordinary telegraph repeater repeats the greater part of such distortion so that it increases cumulatively with the length of the over-all circuit, the maximum distance over which a teletypewriter circuit will operate tends to be limited by this factor. Fortunately, the fact that the signals are of standard length and are transmitted with mechanical uniformity permits the use, in long circuits, of a special type of telegraph repeater, which is capable of eliminating distortion from the signals. This is known as the start-stop "regenerative" repeater. The principle of the regenerative repeater is based upon the operation of a transmitting machine by a receiving machine. The receiving mechanism, instead of typing the message, sets up the code for the transmitting machine which relays it to the next section of the circuit simultaneously with reception. Consisting essentially of a sending and receiving drum or distributor similar to those used in the teletypewriter mechanism, it is capable of receiving without error any set of signals that would be satisfactorily received by an ordinary teletypewriter, and of sending these same signals out as free from distortion as the signals formed by the sending set. Therefore, by spacing regenerative repeaters at intervals that would be sufficiently short

for satisfactory operation of a standard teletypewriter circuit, it is theoretically possible to operate a circuit of any length whatever.

65. Questions for self-examination.—

1. What are the factors limiting the distance over which telegraph will work on a single line?

2. Why are repeaters used?

3. Name three types of repeaters.

4. Could the polar direct-point repeater be replaced by the single-line repeater?

5. Given a double-current differential duplex circuit, show how to convert one of the stations into a repeater station.

6. Is marking or spacing bias cumulative where single-line and polar direct-point repeaters are used?

7. What advantage does the regenerative repeater have over other types?

SECTION IX

TELEGRAPH SWITCHBOARDS

	Paragraph
Requirements of telegraph switchboards	66
Neutral system switchboard	67
Basic circuit with make-before-break relays	68
Relay test circuit	69
Questions for self-examination	70

66. Requirements of telegraph switchboards.—Telegraph switchboards are very similar in many respects to telephone switchboards. Some of their requirements are as follows:

a. Line connections.—The primary need for switchboards is to connect two or more line circuits together in any combination desired. For telegraph switchboards this requires that lines of both ground return and metallic return circuits may be connected together through the switchboard.

b. Communication with stations.—It is, of course, also necessary that provisions exist for communicating with the stations so that they may give the operator necessary instructions as to the connections desired.

c. Signaling.—Means are provided for the stations to signal the operator and for the operator to signal the stations.

d. Supervision.—It is necessary that there be some means for the stations to let the operator know when a connection is no longer desired, so some means of supervision is used.

e. Expansion.—Most telephone switchboards have some means provided for connecting two or more boards in multiple, for increasing the number of lines that may be handled. The same is true for telegraph switchboards.

f. Constant line current.—The current in a telegraph line should remain constant regardless of which or how many circuits are connected to it.

g. Repeaters.—Telegraph switchboards should contain repeaters so that if two stations, each of which is near its maximum working distance from the switchboard, are connected together through

the switchboard they may be able to communicate with each other. Repeaters also solve the problem of maintaining constant line current and making connections between grounded and metallic lines.

h. Distortion correction.—It is desirable, though not always possible, to prevent distortion, occurring in one line, from affecting the signals in another line when the two are connected together. The use of repeaters tends to partially reduce this transfer of distortion.

i. Adjustment of relays.—Since each circuit will terminate in relays at the switchboard, and since the adjustment of these relays depend to a large extent upon variable line conditions, it is of great benefit, though not essential, that there be provided some means of readily checking the adjustment of these relays. This method should be simple and positive. Most switchboards have some means of testing the relay while in the circuit as well as employing interchangeable plug-in type relays.

67. Neutral system switchboard.—The repeaters used in telegraph switchboards are of such type that each circuit is terminated in a half repeater. Essentially each half repeater consists of a sending relay and a receiving relay. The winding of the receiving relay and the contacts of the sending relay are connected in series in the line. When two lines are connected together at the switchboard the contacts of the receiving relay of one line are connected to control the operation of the sending relay in the other line.

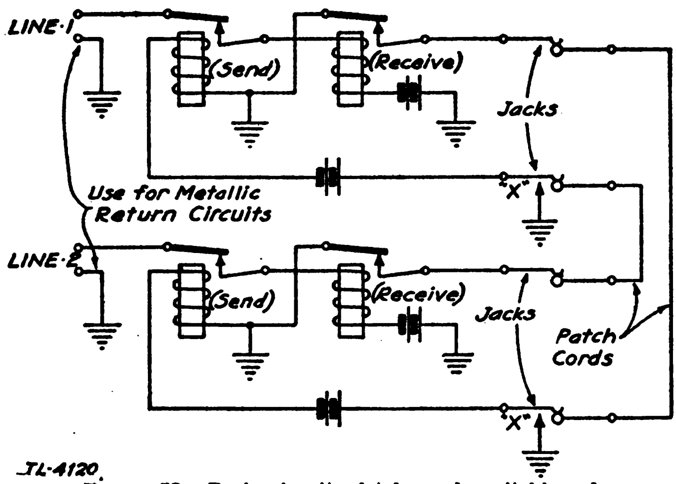

FIGURE 52.—Basic circuit of telegraph switchboard.

a. Basic circuit.—Figure 52 shows the basic circuit used in telegraph switchboards. It can be seen from this circuit that the release of the receiving relay in line *1*, as a result of incoming impulses, controls the operation of the sending relay in line *2* and the contacts of this sending relay transmit the impulses on to line *2*. The use of the simple neutral type relays in this circuit, however, presents another problem. Upon study of figure 52 it can be seen that if the receiving relay of line *1* is released and, as a result, the sending relay of line *2*; then the opening of the contacts of this sending relay will cause the receiving relay of line *2* to release, opening the circuit of the sending relay of line *1*, and both circuits will then be locked open. Some method must be used to prevent the release of a receiving relay as a result of the sending relay in the same line circuit being released.

b. Make-before-break relay.—A solution to the problem has been found in the use of the make-before-break type relay. This relay has an additional contact as shown in figure 53. The relay armature closes with a make contact which is somewhat flexible and as the armature continues in its movement the make contact is pulled away from the break contact. Thus, when released as in

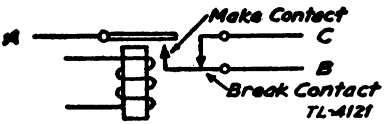

FIGURE 53.—Make-before-break relay.

figure 53 the circuit is closed from *B* to *C*, but as the relay is operated the circuit is first closed from *A* to *B* and then opened between *B* and *C*.

68. Basic circuit with make-before-break relay.—Figure 54 shows the basic circuit of the telegraph switchboard employing a make-before-break relay as the sending relay. All relays are shown in the normal or operated position. If a spacing impulse is transmitted from line *1* the receiving relay of that line circuit will release. The circuit from ground through the receiving relay contact of line *1*, the patch cord, battery, sending relay of line *2* and back to ground will now be opened. This causes the sending relay of line *2* to release, transmitting the space impulse to line *2*. Opening the sending relay contacts of line *2* does not release the receiving

relay of line *2* because of the holding circuit completed through the make-before-break contact arrangement. When there are no patch cords connected into a line circuit the sending relay is held operated by a grounded contact in the jack at point *X* in figures 52 and 54.

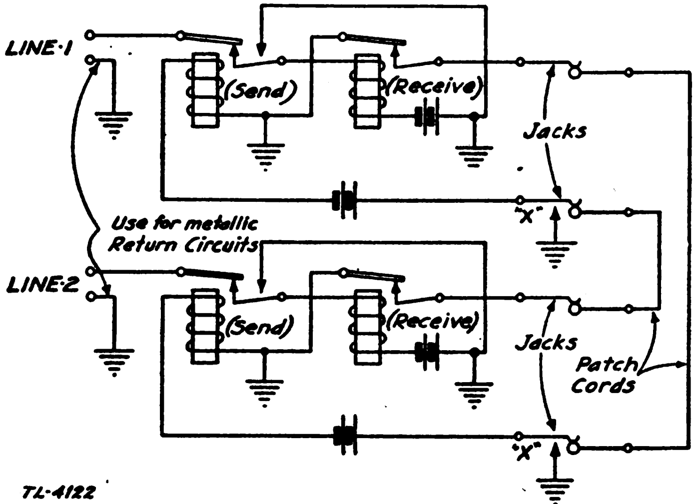

FIGURE 54.—Basic circuit of telegraph switchboard with make-before-break relay.

a. Signaling.—Signaling may be accomplished through any one of several methods. One of the most common is the use of additional contacts on the receiving relay which controls the action of a slow acting relay. If the line circuit is held open (by use of the break key on the teletypewriter) for a long period as compared to the open period occuring during the transmission of signals, the slow acting relay will release, closing a circuit for a signal lamp. The normal opening and closing of the receiving relay contacts during transmission is too fast to permit the slow acting relay to release and no lamp signal is received unless the break key is held depressed for at least a second or two.

b. Supervision.—Supervision by the operator may be obtained either by separate supervisory signals as in commercial switchboards, or by use of the line signals as in the army switchboard BD–100. Generally in a neutral system when the connection is no longer desired the station originating the call should recall the operator to notify him that the connection may be taken down.

This method of supervision is similar to that employed by the local-battery magneto telephone system. If the operator's circuit is terminated in a manner similar to that of a line circuit the operator may be connected to any circuit by means of patch cords or key arrangements. Line circuits appear in two jacks with patching being completed from the top jack of one circuit to the lower jack of the other circuit. In this manner conference connections, where several circuits are connected together at one time, are possible. Since each circuit is individually terminated, patching connections may be made between line circuits connected to separate switchboards when these switchboards are located together. This provides for expansion of an office. For the same reason line currents will not be affected by patching so that connections may be made between line circuits of stations which would otherwise be too far apart for communication.

c. *Adjustments.*—The line circuits usually include a rheostat for varying the line current and a key arrangement for connecting a milliammeter into the line to measure the line current. The tension on the relay springs should be adjusted so that as the relay receives a given signal its contacts will transmit it on with the proper time intervals. The contacts should be closed and opened in accordance with the signal to be transmited. If the tension is too great the contacts will tend to stay open longer than they should, and likewise if the tension is too light they will be slow in releasing and stay closed too long. A special test circuit is often provided for testing the relay contacts. This test circuit is referred to as a bias testing or relay test circuit.

69. Relay test circuit.—Vibrating relay contacts may be considered as having an effective resistance over a period of time. When the contacts are closed their resistance is zero and when open it is infinite. Over a period of time it may be considered that they have a resistance which depends upon the resistance of the circuit in series with the contacts and the proportion of time when the contacts are closed. If the resistance of the circuit in series with the contacts is 1500 ohms it will be found, for example, that the effective resistance of the contacts transmitting a continuous space bar signal, as shown in figure 31, will be 3115 ohms. As stated before, this value will vary with the value of resistance in series with the contacts and is given merely as an example. The relay test circuit, figure 55, consists of a Wheatstone bridge employing

the effective resistance of the relay contacts as one arm of the bridge. In making the adjustments the signals must be transmitted continuously while the spring tension is being changed. With teletypewriters the signal which can be transmitted most conveniently

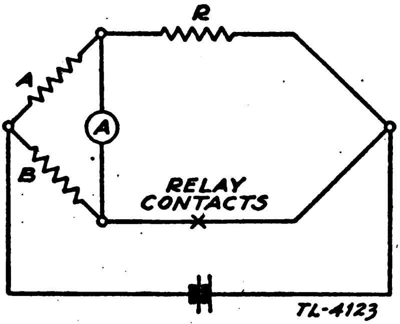

FIGURE 55.—Relay test circuit.

for this test is that which is transmitted when the space bar of the teletypewriter is held down. For this reason the bridge is designed so that it will be balanced when the relay contacts present an effective resistance equal to that corresponding to the continuous space bar signal. The relay contacts are then connected into the test circuit, the space bar of the teletypewriter is held down and the spring tension is adjusted until the bridge is balanced. In testing the receiving relay contacts the distant station will transmit the space bar signals, and in testing the sending relay the transmissions must be toward the distant station.

70. Questions for self-examination.—

1. What features are desired in telegraph switchboards?
2. Explain the operation of a make-before-break relay.
3. Draw the basic circuit with make-before-break relays and explain its operation in terminating a line at a telegraph switchboard.
4. How may conference connections be obtained in a telegraph switchboard?
5. What types of adjustments are necessary in telegraph switchboards?
6. Explain the operation of the relay test circuit.

APPENDIX I

INDEX TO TECHNICAL AND FIELD MANUALS

(See FM 21-6 for complete list)

TM 11-302	Charging Set SCR-169
TM 11-330	Switchboards BD-71 and BD-72
TM 11-331	Switchboard BD-14
TM 11-332	Telephone Central Office Set TC-4
TM 11-333	Signal Corps Telephone EE-8-A
TM 11-335	Telephone Central Office Set TC-1
TM 11-340	Telephone Central Office Set TC-2
TM 11-345	Cabinet BE-70-( ), Wire Chief's Testing Cabinet
TM 11-351	Telegraph Sets TG-5 and TG-5-A
TM 11-353	Installation and Maintenance of Telegraph Printer Equipment
TM 11-354	Teletypewriter Sets EE-97 and EE-98
TM 11-360	Reel Units RL-26 and RL-26-A
TM 11-361	Signal Corps Test Sets EE-65 and EE-65-A
TM 11-362	Reel Unit RL-31
TM 11-363	Pole Line Construction
TM 11-430	Storage Batteries for Signal Communication, except those pertaining to aircraft
TM 11-431	Target Range Communication Systems
TM 11-457	Local-Battery Telephone Equipment
TM 11-458	Common-Battery Telephone Equipment
TM 11-900	Power Units PE-75-A and PE-75-B
TM 11-901	Power Unit PE-75-C
FM 1-45	Signal Communication; Air Corps
FM 5-10	Communication, Construction, and Utilities; Engineer
FM 11-5	Missions, Functions, and Signal Communication in General; Signal Corps
FM 24-5	Signal Communication

APPENDIX II

GLOSSARY OF TERMS

The following definition of words and terms apply only to their usage in this text.

Alternating current—Current that periodically reverses in direction.

Alternator.—An a-c generator.

Ammeter.—A current meter with a scale calibrated in amperes.

Ampere.—Unit of flow of electrical current; i.e. that amount of current which will flow through a resistance of one ohm when a potential of one volt is applied.

Armature.—The rotating assembly of a d-c motor or generator; also the movable iron part which completes the magnetic circuit in certain apparatus.

Battery.—A device for converting chemical energy into electrical energy; one or more cells.

Bias.—*Line bias.*—The effect on the length of telegraph signals produced by the electrical characteristics of the line and equipment. If the received signal is longer than that sent, the distortion is called marking bias; if the received signal is shorter, it is called spacing bias.

Applied bias.—A force (electrical, mechanical, or magnetic) exerted on a relay or other device which tends to hold the device in a given electrical or mechanical condition.

Bias distortion.—The distortion produced by bias.

Break contact.—That contact of a switching device which opens a circuit upon the operation of the device.

Break key.—On a teletypewriter the key used to break into the transmission being received from another station.

Bridge.—A shunt path; a device used in the electrical measurement of impedance, resistance, etc.

Bypass.—A shunt path around some element or elements of a circuit.

Capacitance.—The ability or capacity to receive an electrical charge.

Capacitor.—A device for inserting the property of capacitance into a circuit; two or more conductors separated by a dielectric.

Cell.—A combination of electrodes and electrolyte which converts chemical energy into electrical energy.

Characteristic.—A distinguishing trait, quality, or property.

Circuit.—A closed path or mesh of closed paths which may include a source of emf.

Closed-circuit System.—A telegraph system in which, when no station is transmitting, the circuit is closed and current is flowing in the circuit.

Composite.—A method of simultaneously operating telephone and d-c telegraph circuits over the same conductors in which one telegraph circuit may be obtained on each conductor.

Condenser.—Same as capacitor.

Continuity.—A condition of a circuit where a closed electrical path is obtained.

Cross.—A type of line trouble in which one circuit becomes connected to one or more other circuits.

Crossfire.—A condition where telegraph signals on one circuit cause interference in other telegraph or telephone circuits.

Current.—A flow of electrons in a circuit.

Direct current.—Current which is constant in direction.

Differential.—Pertaining to, or involving, a difference; i.e., a differential current device is one which operated upon the basis of a difference in two current values.

Distortion.—An alteration or deformity of a wave form.

Duplex.—Operation in two directions simultaneously over one circuit.

Electrode.—The solid conductors of a cell or battery which are placed in contact with the electrolyte; a conductor which makes electrical contact with a liquid, gas, or an electron cloud.

Electrolyte.—A solution in which, when traversed by an electric current, there is a liberation of matter at the electrodes, either an evolution of gas or a deposit of a solid. Usually refers to the solution in a battery.

Electromagnet.—A core of magnetic material, such as soft iron, which is temporarily magnetized by passing an electric current through a coil of wire surrounding it, but loses its magnetism as soon as the current stops.

Electromotive force.—*emf.*—Difference of electrical potential or pressure measured in volts.

Electrons.—One of the negative particles of an atom.

Energy.—That capacity for doing work.

Field of force.—Region in space within which a force is effective.

Flux.—The magnetic lines of force.

Force.—That which tends to change the state of rest or motion of matter.

Function.—The duty or job performed by a device; with regard to teletypewriters, the mechanical operation of line feed, carriage return, letters shift, figures, unshift and space.

Fuse.—A circuit protecting device which makes use of a substance which has a low melting point.

Generator.—A device for converting mechanical energy into electrical energy.

Ground.—The contact of a conductor with the earth; also the earth when employed as a return conductor.

Holding coil.—A separate coil of a relay which is energized by the operation of the relay and holds the relay operated after the original operating circuit is deenergized.

Howler.—An electromechanical device for the production of an audio-frequency tone.

Impedance.—The total opposition to the flow of current consisting of resistance and reactance.

Inductance.—Property of a circuit which opposes a change in current.

Inductive reactance.—The opposition to the flow of alternating or pulsating current due to the inductance of the circuit.

Insulator.—A medium which will not conduct electricity.

Jack.—In combination with a plug, a device by which connections can readily be effected in electrical circuits.

Key.—A hand operated device for the rapid opening and closing of a circuit or circuits.

Keyboard perforator.—A mechanism consisting of a keyboard and a perforator by which means a tape is perforated in accordance with a code corresponding to the depressed character key of the keyboard.

Leakage.—Term used to express current loss through imperfect insulation.

Lines of force.—A path through space along which a field of force acts. (Shown by a line on a sketch.)

Magnetic pole.—Region where the majority of magnetic lines of force leave or enter a magnet.

Magnetomotive force.—The force which is necessary to establish flux in a magnetic circuit or to magnetize an unmagnetized specimen.

Make contact.—That contact of a device which closes a circuit upon the operation of the device.

Margin.—The upper and lower limits through which the index arm of the range finder mechanism of a teletypewriter may be moved and still receive correct copy.

Marking bias.—That bias which affects the results in the same direction as marking current.

Marking contact.—That contact of a telegraph relay which is closed when marking current is controlling the relay operation.

Marking current.—That magnitude and polarity of current in the line when the receiving mechanism is in the operated position.

Microfarad.—Practical unit of capacitance; one-millionth of a farad.

Milliampere.—Unit of electric current; equal to one-thousandth of an ampere.

Milliammeter.—Current meter with a scale calibrated in milliamperes.

Multiple.—Parallel connection whereby any number of identical pieces of equipment may be connected into the circuit.

Network.—An electrical circuit made up of series or shunt impedance or combinations of series and shunt impedances.

Ohm.—Fundamental unit of resistance.

Ohmmeter.—A direct reading instrument for measuring resistance, calibrated in ohms.

Open-circuit system.—A telegraph system which, when no station is transmitting, no battery is in the circuit and no current is flowing.

Parallel circuit.—A circuit in which one side of all component parts are connected together to one line while the other side of all components are connected together to another line.

Patching.—The temporary connection of the two lines or circuits together through other than the use of regular switchboard cord circuits.

Patching cord.—A cord terminated on each end with a plug, used in patching between circuits terminated in jacks.

Permanent magnet.—A piece of steel or alloy which has its molecuies lined up such that a magnetic field exists without the application of a magnetomotive force.

Phantom circuit.—A telephone circuit which is superimposed upon two other circuits such that the two conductors of one circuit act combined as one conductor for the phantom circuit and the conductors of the second circuit act as the other phantom conductor.

Plug.—In combination with a jack, a device by which connections can readily be effected in electrical circuits.

Polar.—A system of telegraphy in which the current in the line is reversed in polarity in changing from marking to spacing.

Polarential.—A telegraph transmission system in which transmission in one direction is polar with equal and opposite transmitting voltages for marking and spacing, and transmission in the other direction is differential with voltage applied for the spacing condition and ground for the marking condition.

Potential difference.—The degree of electrical pressure exerted by a point in an electrical field or circuit in reference to some other point; same as electromotive force or voltage.

Prolongation.—That interval of time between the opening of the circuit and the release of the receiving mechanism.

Protector.—A device to protect equipment or personnel from high voltages or currents.

Pulsating current.—Current of varying magnitude but constant direction.

Rectifier.—A device for charging alternating current to pulsating current.

Relay.—A device for controlling electrical circuits from a remote position; magnetic switch.

Repeater.—A device for the retransmission of a signal, usually with amplification.

Repeating coil.—An audio-frequency transformer for transferring energy from one electrical circuit to another, usually one-to-one ratio with one side (line connection) arranged so that a center tap may be obtained for simplexing.

Reperforator.—A device for the reception of teletypewriter signals as electrical impulses from a line and converting them into perforations in a tape.

Resistance.—The opposition offered by a conductor to the passage of either direct or alternating current. That portion of impedance which causes power loss.

Retardation.—The interval of time between the closing of the circuit and the operation of the receiving mechanism.

Rheostat.—A variable resistance for limiting the currents in a circuit.

Rotor.—The rotating part of an electrical device.

Self inductance.—Inductance associated with but one circuit.

Series circuit.—An electrical circuit in which the component parts are placed end-to-end and form a single continuous conductor; opposite of parallel.

Short.—A type of line trouble in which the two conductors of a pair become connected together.

Shunt.—A parallel or alternate path for the current in a circuit; usually with some impedance other than zero; not used with reference to trouble. (See Short.)

Simplex.—A method of obtaining a telegraph channel by use of repeating coils or bridged impedances.

Sounder.—A receiving instrument used in telegraphy to produce audible signals by means of an armature operated between two stops.

Spacing bias.—That bias which affects the results in the same direction as spacing current.

Spacing contact.—That contact of a telegraph relay which is closed when spacing current is controlling the relay operation.

Spacing current.—That magnitude and polarity of current in the line when the receiving mechanism is in the unoperated or released position.

Stator.—That part of an electrical device which remains stationary when in use.

Subscriber.—A person or organization to whom service is extended.

Supervision.—The process of watching over the condition of a connection at a switchboard to determine when subscribers are through using the connection.

Switch.—A device for opening, closing, or rerouting an electrical circuit.

Switchboard.—A board containing apparatus for controlling or connecting electrical circuits.

Synchronism.—The state of being synchronous.

Synchronous.—Having the same period and phase; happening at the same time.

Telegraphy.—A means of communication whereby a message is transmitted a character at a time employing a code of impulses of various lengths and combinations to designate the individual characters.

Teletypewriter.—An electromechanical device for the transmission of characters as electrical impulses, the analysis, and printing of the characters corresponding to the impulses received.

Terminal.—One end of an electrical circuit.

Transmission.—The passing of energy through a conductor.

Transmitter-distributor.—A distributor consisting of a rotating arm with brushes in contact with conducting segments of a circle, used in the transmission of teletypewriter signals.

T.W.X.—A trunk between teletypewriter central offices; in the Army, referred to trunks from Army teletypewriter switchboards to commercial switchboards.

Volt.—Unit of potential, potential difference, emf, or electrical pressure.

Voltmeter.—An instrument for measuring potential difference or electrical pressure, calibrated in volts.

Working margin.—The difference in current through the line relay of the receiving telegraph station when the key of the sending telegraph station is open and when it is closed.

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BY ORDER OF THE SECRETARY OF WAR:

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